FACTORS INFLUENCING ADOPTION AND

USE OF PRECISION AGRICULTURE

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USE OF PRECISION AGRICULTURE

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# DISSERTATION ABSTRACT

FACTORS INFLUENCING ADOPTION AND

USE OF PRECISION AGRICULTURE

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While the potential for creating efficiencies are possible with precision agricultural tools, the various combinations of tools, the steep learning curve of these technologies, and the initial investment of each of the tools complicate farmers' decisions to adopt these technologies. The purpose of this study is to create a model that describes, explains, and predicts precision agriculture adoption. The research takes a multi-disciplinary approach to studying precision agriculture adoption.

The proposed model is based on the Transtheoretical Model's stage of change and the decision making construct, decisional balance. Additionally, the constructs of precision agriculture self-efficacy, perceived ease of use, and perceived compatibility are integrated in the adoption decision model. A survey instrument was created to measure stage of change, decisional balance, precision agriculture self-efficacy, perceived ease of use, and perceived compatibility.  261 surveys were used in this study to empirically test the adoption-decision model. The results indicated that decisional balance, which is the weighing of importance of the advantages and disadvantages of using precision agriculture did, in fact, predict the stage of change. Additionally, perceived ease of use influenced the decisional balance. Perceived compatibility affected both decisional balance and the stage of change. The study did not find support that precision agriculture self-efficacy directly influenced the stage of change, but precision agriculture self-efficacy did indirectly affect stage of change through decisional balance and perceived ease of use. Farm size also influenced the stage of change, while off-farm employment and educational level did not affect the stage of change.

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# CHAPTER 1

# INTRODUCTION

With advancements in Geographic Information System (GIS) and Global Positioning System (GPS) technologies, farmers now have the ability to make crop production and management decisions based on the variability of the soil properties within fields. The term "precision agriculture" describes the integration of GIS and GPS tools to provide an extensive amount of detailed information on crop growth, crop health, crop yield, water absorption, nutrient levels, topography, and soil variability. This information provides mechanisms to manage areas within fields differently, according to the soil and crop characteristics. Some farmers and researchers assert that precision agriculture technologies assist farmers in managing their farms more effectively. Specific objectives of precision agriculture are to increase profitability, increase production, reduce variable costs, reduce erosion, reduce the environmental impact of chemicals, track and monitor the use of chemicals, and manage large farms (Atherton, Morgan, Shearer, Stombaugh, & Ward, 1999; Olson, 1998).

Crop production is largely dependent on the characteristics of the soil in which they are grown. Farmers, since the advent of the tractor in the 1920s, have managed farms with a whole-field approach. Traditional farming (or the whole-field approach) requires farmers to apply inputs at the same rate across fields, regardless of the inherent variation in the soil and landscape. For example, farmers apply the same amount of fertilizer throughout the fields, regardless that some of the areas need more, or less, fertilizer. Precision agriculture tools offer various functions. Some are information gathering tools, such as yield monitors, targeted soil sampling, and remote sensing tools. Other tools are variable rate technologies that vary the rate of fertilizer, seeds, and pesticides. Additionally, guidance systems, such as light bars and auto steer equipment, help the operator guide the equipment.

Since the incorporation of precision agriculture tools began in the mid-1980s, initial adoption has been slow (Swinton & Lowenberg-DeBoer, 1998). Adoption of precision agriculture is progressing, though. A 2003 farm survey indicated that 32 percent of Ohio farmers has adopted at least one precision agriculture tool (Batte, 2005). While there seems to be a plethora of agronomic and economic research related to precision agriculture, the social sciences have been slow in analyzing the adoption and use of precision agriculture (Lowenberg-DeBoer, 1996). Little is known about why farmers decide to (or not to) adopt these technologies. The purpose of this study is to create a model that describes, explains, and predicts farmers how make decisions whether or not to adopt precision agriculture technologies.

## Precision Agriculture Technologies

Precision agriculture tools are used to monitor crop yields, to apply inputs at a variable, rather than at a constant rate, and to guide equipment. These tools are used to determine soil electrical conductivity, manage soil on a site-specific basis, and to monitor crop growth and health from satellite or aerial images. All of these tools use

GIS to acquire, process, analyze, and transform the data that farmers can use to better manage production and increase profitability. GPS units are used to guide equipment during chemical and irrigation applications and during harvest (Adrian, Dillard, & Mask, 2004).

Precision agriculture technologies are used for different purposes, and in various combinations, to fit the needs of individual producers. The information gathering tools, such as yield monitors, targeted soil sampling, and remote sensing, provide information about the fields as they vary in soil chemistry, moisture, fertility, topography, and productivity (yields). This information is entered into GISs that map these varying characteristics. The farmer uses GISs to create management zones which identify subsets of the fields that hold different soil properties and production potential. Farmers enter the appropriate rates of the inputs (i.e., fertilizer) for each management zone into the GIS. The management zone mapping from the GIS is then incorporated into variable rate applicators so the inputs are applied appropriately as the equipment passes through the fields.

## Yield Monitors

One information gathering tool is the yield monitor. Yield monitors are devices installed on crop harvesting equipment, such as combines or cotton pickers. Yield monitors collect information about the yield of the crop as the equipment travels through the fields. Yield monitors are the most widely adopted precision agriculture tool (Precision Ag, 2005; Swinton, Marsh, & Ahmad, 1997). Yield monitors use GPS, GIS, computer, and sensor technologies to accurately measure the amount of crop harvested and moisture content of the crop at a specific location and time. Data gathered from yield monitors are transformed and transferred into the GISs so farmers can create detailed harvest reports, determine trends from harvest to harvest, compare the production capabilities of different varieties and crop inputs, and create management zones.

## Targeted Soil Sampling

The soil type and its physical and chemical characteristics must be in proper balance to maximize production potential. Targeted soil sampling is a method to determine the chemical characteristics of the soil (i.e., acidity levels and nitrogen levels). Targeted soil sampling consists of two primary methods, grid and zone sampling. In each method, GIS software is used with the GPS to create a boundary of a field and divide the areas within the boundary into individual segments of grids or zones. Grids are normally square in shape and range in size from one-half to two and one-half acres in size. Zones are generally not uniform in shape, or size, and are often based on Natural Resource Conservation Service (NRCS) soil maps, areas of similar yield production, or any variable used for delineation. GISs provide the capability to collect and view soil sampling data. By using targeted soil sampling, farmers collect site-specific information that is used to make decisions on how to vary inputs in the management zones.

## Remote Sensing

Remote sensing, another information gathering tool, provides aerial and satellite images of the crop during its growing season. Remotely sensed data transferred to a GIS reveals information about soil characteristics, such as moisture content and general crop health. Remotely sensed data gives farmers near real-time information regarding their crop which allows them to make corrective management decisions by rectifying deficiencies before the crop is ready for harvest. This remotely sensed data, entered in a GIS, is used to make decisions on varying the rates of inputs in the management zones. This information is then transferred to variable rate applicators which apply the inputs as specific in the GIS.

### Variable Rate Applicators

Variable rate applicators allow farmers to vary inputs, such as fertilizers, pesticides, seed varieties, and seeding rates throughout fields based on data retrieved from the information gathering tools. The input rates for management zones are entered into the GIS. This information is then transferred to the GPS-controlled variable applicator which is attached to the equipment. The purpose of varying input rates is to increase yields or reduce costs, depending on the managers' goal for the management zones.

### Equipment Guidance Systems

Equipment operators have traditionally relied on visual cues, such as points on the horizon, marking systems consisting of foam emitters, tire tracks, or by counting number of rows to begin the next application pass. These methods lack the accuracy needed to avoid skips and overlaps. Additionally, they do not work at night. Equipment guidance systems, placed on agricultural machinery, are used to assist in steering the equipment in a more concise pattern by integrating GIS, GPS, on-board computing, and directional indicator devices to keep the machinery traveling in the most efficient manner across a field (Adrian et al., 2004).

Auto steer equipment and light bars are two of the most widely used guidance tools. The lightbar uses a directional indicator device that provides navigational information to the operator. The auto-steer systems, similar to lightbar systems, actually steer the machinery, instead of the equipment operator. Auto-steer systems use a real-time kinematic form of GPS that incorporates a base station located on the farm that sends GPS data to the antenna located on the equipment. These guidance systems reduce redundancy, reduce labor costs, and expand hours of operation (Adrian et al., 2004).

While some researchers have found that precision agriculture tools are adopted sequentially (Isik, Khanna, & Winter-Nelson, 2000), others have found that the full potential of the individual components will not be realized unless the components are used as a set. For instance, the information captured with the yield monitor must be referenced and stored in a GIS. Next, maps are created and analyzed. Then, a variable rate applicator is used to vary chemicals throughout the fields (Batte, Pohlman, Forster, & Sohngen, 2003) according to the potential production of the grid or management zones.

## Precision Agriculture Research

The rapid growth of precision agriculture has sparked research in many areas to include agronomic evaluation of these technologies, development of appropriate uses of the technologies, demographic patterns of use of these technologies, and economic and environmental benefits of the technologies. The demographic research has focused on farm size (Khanna, 2001), farming experience, education (Hudson & Hite, 2003), access to information (Daberkow & McBride, 2003), location of the farm, and physical attributes of the farm, such as variability of soil types and crops grown. Most economic research in precision agriculture has focused on the profitability of specific tools in specific commodities (Swinton & Lowenberg-DeBoer, 1998).

Very little attention has been given to the perceptions and attitudinal reasons for farmers to adopt these technologies (Adesina & Baidu-Forson, 1995; Cochrane, 1993). Evaluating the perceptions and attitudes of farmers can lead to understanding why farmers adopt technologies beyond the economic benefit, and what industry and researchers may focus on to affect adoption of these technologies. Furthermore, the omission of producers' attitudes toward the technologies studied may lead to biased results (Adesina & Zinnah, 1993).

A few studies have examined producers' attitudes toward precision agriculture (Adrian, Norwood, & Mask, 2005; Napier, Robinson, & Tucker, 2000; Swinton et al., 1997). Swinton et al (1997) used focus groups to identify several barriers to adopting precision agriculture. Two of these barriers were concerns over the initial cost of the technologies and keeping up with technologies that are rapidly changing. Napier et al. (2000) investigated producers' perceptions of the importance of conservation practices and having environmental information for management purposes and their intentions for using precision agriculture. They also investigated the farmers' perceptions of their ability in using precision agriculture. Napier et al. (2000) found that farmers who perceived that they would receive returns on conservation investments and that conservation information was important in farm management decision-making were more likely to adopt precision agriculture. The farmers' perceptions of their ability to use precision agriculture were not a significant factor in the intention to adopt precision agriculture.

Conversely, Adrian et al. (2005) found that farmers' confidence in using precision agriculture affected the intention to adopt of precision agriculture technologies. They also found that the farmers' perceptions of net benefit affected the intention to use precision agriculture technologies. The perceptions of ease of use were not a significant factor affecting the intention to adopt precision agriculture.

## An Interdisciplinary Approach to Studying the Precision Agriculture Adoption Decision Process

Precision agriculture technologies are used to manage specific areas of fields and to achieve long-term goals of sustainability by providing historical information on the soil and crop variations throughout farmers' fields. Precision agriculture also provides accurate recordkeeping for government regulations. Some researchers see precision agriculture as part of the larger context of Information Systems (IS) in agriculture (Sonka & Coaldrake, 1996). Just as IS is not a homogenous product (Markus & Robey, 1988), neither is precision agriculture. Rather, precision agriculture is the use of the various combinations of tools used for strategic, tactical, and operational improvement of agriculture production (Bouma, Stoorvogel, van Alphen, & Booltink, 1999; National Research Council, 1997).

While the potential of creating efficiencies exists with precision agricultural tools, these tools are fundamentally changing the way farmers make production decisions (Sonka, 1998). Precision agriculture is an integration of GIS and GPS tools that can be used in a variety of combinations that fit the goals and operations of the farm manager. The steep learning curve of these technologies and the initial investment of each of the tools complicate farmers' adoption decisions. Part of the difficulty of researching these factors is that precision agriculture is not one particular tool, such as the motorized tractor, or a particular practice, such as no till farming. Farmers must decide which tools and software will provide efficiencies for their situations.

The IS field offers many methodologies for investigating technology diffusion, the intention to adopt information technologies, and attitudes and perceptions toward these technologies. Many of these methodologies borrow from the psychology, sociology, and organizational change theories. The IS field has established several streams of research that could be used in studying precision agriculture adoption, assimilation, and use.

One theory borrowed from psychology is the Theory of Reason Action (TRA) which defines attitudes toward a technology as the individual's beliefs about the consequences of adopting and using the technology and the assessment of these consequences (Fishbein & Ajzen, 1975). Attitudes toward a technology, particularly individuals' perceptions of their own capabilities and beliefs they can learn to use technology (Compeau & Higgins, 1995; Necessary & Parish, 1996; Rainer & Miller, 1996), affect whether individuals will adopt the technology (Chau, 2001; Davis, 1989; Milbrath & Kinzie, 2000). Further, attitudes of confidence in producers' abilities, have not been studied in the adoption and use of precision agriculture technology.

From sociology, Diffusion of Innovation (DoI) (Rogers, 1983) indicates that perceptions of relative advantage, complexity, and compatibility with values and operations will affect adoption of technology. Additionally, exposure to technology and interpersonal communication also affect the intention to adopt technologies (Rogers, 1983).

Additionally, psychology offers other methods of explaining and predicting behavioral change and technology adoption. The Transtheoretical Model (TTM), developed in the 1980s (Prochaska & Norcross, 2001; Prochaska, Velicer, DiClemente, & Fava, 1988) predicts and explains behavioral change based on stages that one moves through as one is considering a change, then prepares for the change, makes the change, and maintains the changed behavior. The TTM incorporates how individuals value the advantages and disadvantages of behavioral change. Although the TTM has not been used in IS research, the model could be useful in analyzing the behavior change associated with adoption of technologies. The TTM is used as the basis of this study, along with TRA and DoI.

## Summary

Adoption of technology is not easily predicted solely on its potential economical benefits. Other factors affect farmers' decisions to adopt new technology (Cochrane, 1993; Vanclay, 1992). Utilizing the IS field is a logical choice in researching precision agriculture adoption because precision agriculture technologies are IS, mostly geographical in context, that are used to make management decisions and operate more efficiently (Bouma et al., 1999; National Research Council, 1997). Additionally, other disciplines offer methodologies for studying the precision agriculture adoption-decision process. The IS field has borrowed from psychology and sociology disciplines in creating models that explain the use of information technologies.

Although the TTM has never been used in the IS field, it offers a process that could be useful in explaining the precision agriculture adoption decision. This study develops a model using the TTM and the stage of change as its focal point. Other theories from organizational change, sociology, and psychology are also used in developing this model to explain the precision agriculture adoption-decision process.

# CHAPTER 2

# LITERATURE REVIEW

Theories from sociology, business, and psychology offer models from which a theoretical framework can be built to explain the cognitive and affective processes of change that producers go through when making the decision to adopt new technologies, such as precision agriculture. Although researchers have used cognitive and affective attributes to study adoption of technology in organizations, these attributes have seldom been studied in the agricultural industry.

Three theories are particularly applicable in understanding the decision process for adopting and implementing precision agriculture technologies. These are the Information-Decision Process Model (IDPM), the Creating Readiness of Change Model (CRCM), and the TTM. Using the IDPM, Rogers (1995) explained how innovations diffuse throughout social systems. This model describes information-seeking and information-processing activities as part of the decision-making process. As individuals learn more about an innovation, the uncertainty about an innovation decreases. Armenakis, Harris, and Feild (1993) developed the CRCM to explain how communicating the advantages of change, confidence, and support in organizations can influence the readiness of organizational members to embrace change. The TTM (Prochaska & Norcross, 2001; Prochaska et al., 1988), developed by psychologists, explains how to facilitate behavioral change across a wide range of health behaviors by stage-matching interventions. They have more recently applied their stage of change framework to organizational changes (Cunningham et al., 2002; Levesque, Prochaska, & Prochaska, 1999, 2001; Prochaska, Levesque, Prochaska, Dewart, & Wing, 2001; Prochaska, Prochaska, & Levesque, 2001).

These models offer guidance for understanding individuals' attitudes explaining the intention, adoption, and acceptance of new technologies. While each model has its advantages and has been applied in different environments, adapting each model to the adoption process of precision agriculture has certain challenges. No one model is satisfactory in explaining the stages of adoption of precision agricultural technologies. Therefore, this study develops an integrated model, including applicable portions of the three models, to describe, explain, and predict the stage of change associated with the precision agriculture adoption-decision process.

Additionally, the IS research field offers methodologies useful in determining the adoption of information technologies. Because precision agriculture technologies are IS, mostly geographical in context, that are used to make better management decisions and operate more efficiently (National Research Council, 1997; Swinton & Lowenberg-DeBoer, 1998), borrowing from the IS field is a logical choice in researching precision agriculture adoption.

Davis (1989) developed the Technology Acceptance Model (TAM) which examined perceived usefulness and perceived ease of use as predictors for software application use. It has been used extensively and expanded for the past decade. Moore and Benbasat (1991) enhanced the model to include three other characteristics of technology defined by Rogers (1995) as important indicators of innovation acceptance. Moore and Benbasat (1991) included compatibility, demonstratability, and trialability, as well as relative advantage and complexity in their model.

The purpose of this study is to create a model that describes, explains, and predicts the stage of change associated with the precision agriculture adoption-decision process. The TTM model is the basis for modeling the stage of change associated with the adoption of precision agriculture by incorporating appropriate theories from IDPM, CRCM, and IS research.

## Development of a Precision Agricultural Stage of Change Model

The stages described in the TTM and in the IDPM offer different approaches, but they are similar. The central organization of TTM is based on the five stages of change (Prochaska et al., 2001) that people go through when becoming aware of the possibility of the change, the decision to adopt, the implementation of the change, and the maintenance of the change. Prochaska and his colleagues posited that individuals go through ten processes of change during the five stages of change. The TTM has been used extensively in behavioral research for more than twenty years and has more recently been used in organizational change research (Cunningham et al., 2002; Levesque et al., 1999, 2001; Prochaska et al., 2001; Prochaska et al., 2001). Rogers' IDP model was used in the 1950s and 1960s in agriculture (Beal, Rogers, & Bohlen, 1957; Beal & Rogers, 1960), in medicine (Coleman, Katz, & Menzel, 1966), and in education (Lamar, 1966). These studies found evidence that stages exist.

Understanding the factors that affect the stage of change is important to advance and enhance the adoption process. In studying the precision agriculture adoption-decision process, a researcher may ask: What factors influence the stage of change of adoption? The CRCM posits that before individuals are willing to change, they must see that there is value in changing, understand that the change is appropriate, and have the ability to change (Armenakis & Harris, 2002; Armenakis, Harris, & Feild, 1993, 1999).

Other factors can affect individuals' acceptance of new technologies. In the IDPM, Rogers (1995) explained that the socioeconomic characteristics of knowledge, personality, innovativeness, communications behaviors, prior experience, and social norms can affect the decision-making process. While the CRCM recognized that potential adopters' characteristics are important in addressing the readiness for change, the model does not specifically identify what characteristics are important.

Prochaska and his colleagues identified five stages of change in the TTM (Adesina & Baidu-Forson, 1995; McConnaughy, Prochaksa, & Velicer, 1983; Prochaksa, DiClemente, & Norcross, 1992) as precontemplation, contemplation, preparation, action, and maintenance. Each stage is represented by a time period, implying that the change will occur over time. This study uses the TTM as the basis of stage of change in the adoption of the precision agriculture process. The next section of this chapter describes the stage of change as potential adopters of precision agriculture make their decisions to adopt these technologies. The second section of this chapter describes the decisional balance and processes of change as the decision to adopt precision agriculture evolves. Lastly, the chapter identifies the characteristics that would influence the decision to adopt precision agriculture technologies.

## Stage of Change: The Transtheoretical Model

The TTM integrates four theoretical constructs: stage of change, decisional balance (Janis & Mann, 1977), self-efficacy, and processes of change to explain behaviors associated with the decision to change behaviors. The central organization of the TTM is based on the five stages of change (Prochaska et al., 2001): precontemplation, contemplation, preparation, action, and maintenance. Individuals modify their behavior as they move through these five stages. Rogers' (1995) also described a five-stage model that he called the Innovation-Decision Process (IDPM). The model describes the cognitive activities and decisions that, over time, decrease uncertainty about an innovation. He identified the five stages as: knowledge, persuasion, decision, implementation, and confirmation. In Diffusion of Innovations, Rogers (1995) recognized the TTM and compared the five IDPM stages to the five TTM stages (pg 190).

The precision agriculture stage of change model is built around the TTM. A practical advantage of the TTM is that it offers a method to match interventions with the stage of change the individual is in, thus improving the effectiveness of the change efforts. Change agents use the model to access the potential adopter's stage, and then adjust and match the activities—identified as the processes of change—and communications that would help the potential adopter progress through change. The advantage, from a research viewpoint, is that the TTM provides methods for identifying the stage of change and the development of the decisional balance (Armitage, Sheeran, Conner, & Arden, 2004). Thus, the model presented in this research is built around the TTM and is complimented by applicable portions of the IDPM and the CRCM.

The TTM is based on changes that progress, over time, through a series of stages. These covert and overt activities facilitate the movement from one stage to the next stage. These processes, shown in Figure 1, are described as they would apply to the stage of change of using precision adoption to capture crop and field information for improved crop production and management strategies. Change agents would use these processes of change as strategies to help potential adopters progress from one stage to the next. The ten cognitive and behavioral strategies used are consciousness raising, dramatic relief, environmental reevaluation, self-liberation, reinforcement management, helping relationship, counter-conditioning, and stimulus-control. Some strategies are used more in some stages than others. For instance, reinforcement management is used more to progress from the action stage to the maintenance stage than in the earlier stages. The processes are mentioned as part of this literature review because of the theoretical importance in the TTM. Figure 1 shows where each process (or activity) is used in relation to the appropriate stage. This study did not measure the processes of change.

The original research (McConnaughy, DiClemente, Prochaksa, & Velicer, 1989; McConnaughy et al., 1983) identified four stages— precontemplation, contemplation, action, and maintenance. However, subsequent studies

<table>
<tr><th>Precontemplation</th><th>Contemplation</th><th>Preparation</th><th>Action</th><th>Maintenance</th></tr>
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<tr><td colspan="2">Environmental reevaluation<br>Consider how precision agriculture will have a positive impact on the farm.</td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td colspan="2">Self-liberation<br>Believe that one can use precision agriculture and commit to using precision agriculture.</td><td></td></tr>
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Figure 1. Stage of change and processes of change

(DiClemente et al., 1991; Prochaksa et al., 1992) revealed five stages—precontemplation, contemplation, preparation, action, and maintenance. The researchers used a different statistical method and found a stage between contemplation and action that was not recognized in the initial studies. The new stage was named preparation, representing actions that prepare individuals for a behavioral change (Prochaksa et al., 1992). Additionally, Reed (1994) divided that precontemplation stage into two subcategories for non-believers and believers.

## Precontemplation

Precontemplation is the initial stage when individuals may not know that the technology exists or may know only a little about it. Individuals in this stage are making no efforts to change. Prior to becoming aware of an innovation, individuals may not see a need for a change (Armenakis et al., 1993; Prochaska et al., 2001; Rogers, 1995) or realize that the technology is appropriate for their operations (Armenakis et al., 1993). Individuals in the precontemplation stage tend to avoid changing their thinking and behavior. Agricultural producers may not see that precision agriculture is a possibility or may not be aware of these technologies or how they can work within their farm operations. The knowledge seeking activities are mainly cognitive and the forming of an attitude about the technology begins in the next stage (Rogers, 1995). In this study, individuals in the precontemplation stage have no intention of adopting the technology.

## Contemplation

In the **c**ontemplation stage, potential adopters have knowledge of the possibility of a change, and are pondering and considering the change. During this stage, individuals develop an interest in the technology, seek more information, and consider its merits. In this stage, individuals form attitudes about the technology. Rogers (1995) described the second stage as mainly affective as individuals develop attitudes about a technology. In this stage, individuals are motivated to seek innovation-evaluation information. They may obtain information from scientific evaluations and from peers. They may observe the technology being used by fellow farmers or demonstrated by researchers or vendors. They may seek opportunities to try the technology.

In the contemplation stage, individuals are seriously thinking about changing, and they use consciousness-raising processes to gather further information. Producers ponder and consider the technology for their operations, accept information that precision agriculture is a viable technology, and form positive or negative attitudes about it. To progress from precontemplation to contemplation, individuals use consciousness to increase awareness and information about the technology and its benefits. As individuals' awareness of the technology increases, they become knowledgeable of the technology's benefits and its use (Levesque et al., 2001; Rogers, 1995). They also use dramatic relief which is a process where the individuals experience negative emotions associated with failure to change or doubting that they have the skills to use the technology. Relief comes with success in using the technology. Producers may question the technologies' success and their ability to use precision agriculture in their farm operations. But, it is through this questioning that they may realize that the technology can have positive benefits (Levesque et al., 2001) on their farm operations and that they have the skills for effective adoption of these tools (Rogers, 1995).

Individuals also use environmental reevaluation to progress from precontemplation to contemplation. This process allows individuals to consider how the technologies will benefit them, how the tools will positively impact them, or how these technologies will fit within their environment (Levesque et al., 2001). The second stage is influenced by how aggressively individuals seek information, what information they receive, and how they interpret the information (Rogers, 1995).

For this study, individuals are considering using precision agriculture, but have not yet planned to adopt these technologies. The producer may have even tried a precision agriculture tool or seen a precision agricultural tool(s) demonstrated, but has not yet decided to use precision agriculture.

Preparation

The preparation stage is when individuals intend to make a change and have made small behavioral adjustments toward making the change. As individuals prepare for a change in behavior or for the adoption of a new technology, they may engage in activities that lead to choices to adopt or reject the innovation. During this stage, individuals are interested in minimizing the risk of adoption of the innovation. One way to minimize risk is to try the innovation without fully adopting it. Farmers may try one or two tools before they are fully convinced that they want to invest in precision agriculture for long term use. The trial could be vicarious when individuals see others using these technologies. Some innovations do not allow for trials and the decision stage may not include a trial step. Change agents use demonstrations to influence the decision of adopting an innovation (Rogers, 1995).

To progress from contemplation to preparation, individuals use self-evaluation. They consider the benefits of the technology and how their environment can be improved by the technology. They consider if the technology is compatible (Rogers, 1995) with their farm management and practices, will meet the needs and goals of their operations, and is an appropriate technology (Armenakis et al., 1993). During this stage, producers consider how the precision agriculture technologies can enhance farm operations. Self-evaluation bridges the gap between the consideration of the tools and adopting them (Levesque et al., 1999). Once in the preparation stage, producers intend to adopt precision technology and begin to engage in learning more about options and ways to use the tools. They often adopt them sequentially (Isik et al., 2000; Khanna, 2001).

In the preparation stage, producers believe that they will adopt precision agriculture in the foreseeable future. In this study, the time period associated with the intention to use precision agriculture technologies is defined as planning to adopt precision agriculture within one year.

### Action

The action stage is when individuals are using precision agriculture on a regular basis (Rogers, 1995). To progress from preparation to action, individuals use self-liberation, becoming committed to using the technologies and believing that they have the capability to learn how to use the tool. Agricultural producers look for ways to utilize the tools and find even more value in using them. Additionally, producers seek help from others and tell others about using these technologies. Farmers talk to other farmers during community activities and often share their successes and/or difficulties using the tools. Some farmers utilize Cooperative Extension agents and consultants for assistance. In this study, the action stage is defined as having used precision agriculture for one to two years.

### Maintenance

In the maintenance stage, individuals are adopting and implementing the change to the point that the change is sustained (Greenstein, Franklin, & McGuffin, 1999). In this stage, individuals seek reinforcement of the innovation-decision that they have already made, but they may reverse previous decisions if they receive conflicting messages about the innovation. They seek to avoid or reduce dissonance, if it occurs, by seeking information that would support their decision. Producers recognize the benefits of using the innovation, integrate the technology into farming operations, and promote its benefits to others (Rogers, 1995). To progress from action to maintenance, individuals use reinforcement management—finding intrinsic and extrinsic rewards for making a change—and counter-conditioning—substituting new behaviors and cognitions for the old ways of working. They also use helping relationships—seeking and using social support to help with the change—and stimulus control—restructuring the environment to make and support the change (Levesque et al., 2001). In this study, the maintenance stage, also labeled as the target behavior, is defined as using precision agriculture for more than two years.

Behavioral researchers describe the progression from one stage to another as cyclical in that individuals may regress to the previous stage(s) (Prochaksa et al., 1992). For instance, someone who is trying to make a health behavioral change by exercising more may move to the action stage and then stop exercising. This individual can freely move from the action stage to the contemplation or preparation stage and back to the action stage. While behavioral researchers have recognized the cyclical behavior of individuals, stage of change research still depends on the linear measurement of the stages.

## Decisional Balance

Janis and Mann (1977) proposed that the Decisional Balance Sheet of Incentives represents both cognitive and motivational aspects of decision making. They identified four main categories in the decision making process: (a) gains and losses for self; (b) gains and losses for others; (c) self-approval or self-disapproval; and (d) approval or disapproval from significant others. The first two categories represent the significant utilitarian considerations during the decision-making process. The second two categories involve social or non-utilitarian aspects, such as self-esteem, social approval, internalized moral standards, and ego ideals. Because precision agriculture promises to improve decision-making that ultimately provides financial benefit, this research uses only the utilitarian consideration as the measure of decisional balance.

The TTM suggests that decisional balance is a predictor of transitions between stages. Decisional balance is defined as the weighing of pros and cons associated with performing a particular task (Armitage et al., 2004; DiClemente et al., 1991; Velicer, Norman, Fava, & Prochaska, 1999). The pros, representing the advantages of changing behavior, increase and the cons, representing the disadvantages of changing behavior, decrease as an individual progresses through the stages (Rosen, 2000). For example, Prochaska (1994) found that to progress from precontemplation to action involves a one standard deviation increase in the pros of making the behavior change and a one-half standard deviation decrease in the cons of making the change. In an agricultural production situation, farmers must see that adopting a new technology provides advantages beyond the costs of investments, time, learning, effort, and risk in adopting it.

Weighing the benefits and disadvantages of making a change predicts the behavior of an individual. Individuals' attitudes, particularly perceptions of the benefits and disadvantages of using a technology, make up the decisional balance. The benefits are the perceptions of value gained from using the technology. The disadvantages are the perceptions of costs to the individual. The costs are not only economic, but are considerations in terms of time, effort, and risk. The weight of the salience of the benefits and disadvantages of using the technologies adjusts during the stage of change. In the earlier stages of change, the disadvantages outweigh the benefits of using the technology. In the later stages, the benefits outweigh the disadvantages. The pros and cons intersect in the middle stages (Prochaska, 1994). The prediction of the stage is based on the difference between the standardized scores of the pros and cons constructs (Janis & Mann, 1977; Velicer et al., 1999) which are independent factors, representing the perceptions of benefits and disadvantages of making a behavioral change. Individuals can rank both pros and cons high, both pros and cons low, or one high and one low (Velicer et al., 1999).

## Pros

The IDPM and the CRCM both emphasize the importance of individuals' perception of the value of the change (Armenakis et al., 1993; Rogers, 1995). The pros construct of the TTM indicates how individuals weigh the importance of the advantage of making a behavioral change. A high pro score in the TTM means that an individual perceives the advantages of making behavioral change as highly important. A person with less salient views of the advantages of making a behavioral change will have a lower pro score.

In the TTM, the perceived benefits (or the pros) of adopting a change increase for each progression to a new stage (Prochaska, 1994). The advantages of precision agriculture can be grouped into three categories: economic benefit, use of information for management strategies, and environmental information.

Economic Benefit

Economic benefit seems to be the deciding factor for sustained use of precision agricultural technologies (Batte & Arnholt, 2003; Cochrane, 1993; Rogers, 1995). Thus, the perceptions of economic value and operational benefits are important to explain the adoption of these technologies. Some economic benefits of precision agriculture include reduced variable costs, increased yields and increased profits (Intarapapong, Hite, & Hudson, 2003; Sawyer, 1994; Wolf & Buttel, 1996). Increasing inputs in more productive areas of managed areas could possibly increase yields. Applying fewer inputs in areas of the field which have lower yield potential reduces variable costs (Intarapapong, et al., 2002). Both increasing productivity and reducing costs should lead to increased profits.

However, analyzing the economic benefits and the costs associated with precision agriculture is difficult and is complicated by other factors (Lowenberg-DeBoer, 1999). Modeling the economic effects of an agricultural production system is complex, difficult, and confounded by the vagaries of economic and environmental factors, such as pests, diseases, and weather. Assessing and determining the most appropriate combinations of inputs and practices to maximize farming profit is a persistent problem that agricultural economists, researchers, and farmers continue to research and debate.

The difficulty in measuring the economic impact of precision agriculture technology is that agricultural production success is dependent on good management on the one hand, and uncontrollable conditions on the other, including weather, pests, government programs, and economic climate. Good management and good decision-making skills, nor unpredictable conditions, can be easily quantified. Furthermore, detailed financial data for the entire farm is not always available to researchers. Therefore, studying the “whole” effect of precision agriculture is problematic.

Some researchers have evaluated the profitability of specific tools on specific crops (Swinton & Lowenberg-DeBoer, 1998; Wolf & Buttel, 1996). These studies indicated mixed results for the use of precision agriculture on profitability (Howard, 1996; Lowenberg-DeBoer, 1996; Sawyer, 1994). When researchers studied the economic impact on specific crops, precision agriculture was found to be profitable on the high value crops, such as sugar beets and potatoes. Precision agriculture technologies used on some small grain crops, like wheat, were not always found to be profitable (Swinton & Lowenberg-DeBoer, 1998).

Precision agriculture technology is still new, changing rapidly, and adjusting to meet the needs of agricultural producers and agribusiness. Similarly, information technology use and development exploded in the 1980s. Prior to 1987, information technology spending did not always demonstrate economic benefits; researchers called this the “productivity paradox.” The National Research Council report (National Research Council, 1997) compared the difficulty of demonstrating economic benefits of precision agriculture to the difficulty of showing economic benefits of information technologies in the 1980s.

Brynjolfsson and Hitt (1996) found that information technology investments were economically beneficial to the firms. They indicated that earlier studies did not show positive correlations between economic measurements and information technology spending because these earlier studies did not have adequate data and had measurement errors. Brynjolfsson and Hitt (1996) matched five years of survey and financial data and used econometrics and production functions as their method of analyses. They concluded that short-term economic effects may not be evident because organizations sometimes must change business processes and capitalize on learning how to use technology effectively.

Some researchers have reasoned that inconsistent results correlating firm performance and information technology adoption occur because this relationship is much more complex than a simple correlation (Chen & Zhu, 2004). The relationship between information technologies and business performance is affected by the business processes and the management of these technologies and how the use of technologies is aligned with business goals and strategies (Bergeron, Raymond, & Rivard, 2001; Chan, Huff, Barclay, & Copeland, 1997; Chen & Zhu, 2004).

Researching and modeling the effects of precision agriculture are equally difficult and complex. Some researchers believe that the mixed results in the economic research is a matter of focusing on a single aspect of farm production, rather than incorporating the effect of decision-making on the whole farm (Lowenberg-DeBoer, 1999; National Research Council, 1997; Swinton & Lowenberg-DeBoer, 1998). Because precision agriculture is a holistic management strategy, the effects on the entire farm should be evaluated (National Research Council, 1997). Traditional cost-benefit analysis does not capture the impact of an investment because the benefits are improved managerial decision making, not just improvement in production efficiencies (Swinton & Lowenberg-DeBoer, 1998).

Management Strategy

In addition to creating efficiencies, precision agriculture also allows for a holistic management of farm production that is not available in traditional farming (Olson, 1998; Lowenberg-DeBoer, 1996). Precision agriculture, as a management strategy, provides for detailed information on a large scale, potentially fundamentally changing the way farmers make production decisions (Sonka, 1998). The National Research Council (1997) report also reported that the value of a vast amount of detailed historical information available through the use of precision agriculture technologies will change farmers' operations, practices, marketing approaches, and management practices. The working definition of precision agriculture, published by the National Research Council (1997) defined precision agriculture as "a management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with crop production". This increased, detailed historical information will be more commonly employed and relied upon for future needs and uses.

Hudson and Hite (2001) found that the second most important motivating factor in precision agriculture adoption is having better information for decision-making. This information provides for management strategies that were not previously possible (Bouma et al., 1999; Lowenberg-DeBoer, 1996; Olson, 1998; Sonka, 1998). The impact of precision agriculture on farm financial performance largely lies in the acquisition of data and information to make more informed decisions on fertilization, crop protection, drainage, variety selection, and other inputs (Batte et al., 2003). As a result, precision agriculture, as a systems approach (Atherton et al., 1999; Davis, Cassady, & Massey; Larkin et al., 2005; Wolf & Buttel, 1996), is a management strategy affecting the entire farm.

Precision agriculture data can be shared with all the participants involved in the processing, marketing, distributing, and consuming of these agricultural products (Wolf & Buttel, 1996). The information pertaining to fungicides, herbicides, pesticides, varieties, and production practices can be tracked during cultivation, harvesting, transportation, processing, distribution, and purchasing. Precision agriculture provides mechanisms to track special characteristics about the crop from time of planting and throughout the growing season. This information includes any application of chemicals, seed variety, and cultivation practices and can be used to differentiate the agricultural product to the consumer who is willing to pay for a specialized commodity (Batte, 2000; Wolf & Buttel, 1996).

Researchers have also suggested that the vast amount of historical site information may provide opportunities for farm growth, gains in market share, greater negotiation power with landlords, and cheaper on-farm experimentation (Olson, 1998; Swinton & Lowenberg-DeBoer, 1998; Wiebold, Sudduth, Davis, Shannon, & Kitchen). Olson (1998) describes the potential of precision agriculture as being able to "…analyze information and make decisions at a small scale … allowing a manager to analyze information and make decisions at a large scale. Better managers will be able to lower costs and improve efficiencies on larger operations…" which will lead them to gain market share. He expects the farms to grow as the results of increased efficiencies and market share.

Some precision agricultural tools, like the guidance systems, allow for longer operating hours, providing opportunities to produce and manage more farm land. Because farmers can keep detailed historical data on the treatment of farmland, they may have greater negotiation power with landlords as the practices and applications of chemicals will be known and shared (Wolf & Buttel, 1996). Additionally, some farmers have used precision agriculture tools to create their own experiments with chemicals and seed varieties (Napier et al., 2000) to determine which inputs work best on their farms.

Environment Information

Because chemical applications can be targeted, one possible benefit of precision agriculture is minimizing the effects on the environment (Khanna, Isik, & Winter-Nelson, 2000; Napier et al., 2000; Swinton & Lowenberg-DeBoer, 1998). Applying chemicals (i.e., fertilizer, fungicides, pesticides) in areas that need these inputs could possibly reduce the amount of chemicals applied and reduce negative impacts on the environment. Researchers have investigated the relationship between precision agriculture and the perception of importance of environmental benefits (Hudson & Hite, 2003; Larkin et al., 2005; Napier et al., 2000; Rejesus & Hornbaker, 1999). These studies found that producers valued the use of precision agriculture to reduce the effects on the environment. However, the value of reducing environmental impact was not the top priority for farmers. Nevertheless, reducing environmental degradation was important to them.

Additionally, environmental monitoring is important (Batte & Arnholt, 2003; Hudson & Hite, 2001, 2003; Napier et al., 2000), particularly as the environmental regulations become more stringent. The Food Quality Protection Act, passed August, 1996, states that with reasonable certainty, no harm must come from the application of pesticides on food. The elevated public concern about the environment increases farmers' needs to track and monitor chemical inputs during farm production.

Precision agriculture tools give farmers the ability to closely track and monitor inputs that have an effect on the environment. Improved record-keeping leads to more accurate, streamlined accounting of the use of chemicals. GIS, serving as an accounting tool, is detailed, accurate, and searchable. GIS provides farmers a mechanism to analyze large amounts of data for year-to-year changes in environmental compliance and gives farmers the ability to show when, where, and exactly how much chemical was applied during crop production. Thus, farmers can more effectively keep records for environmental compliance.

By having more information gained from the use of precision agriculture, farmers have opportunities to make better decisions which should, in turn, lead to improved profits. The potential benefits used in this study include economic benefit, environmental information, and information use for management strategies (Godwin, Richards, Wood, Welsh, & Knight, 2003; Hudson & Hite, 2001; Napier et al., 2000; Olson, 1998; Rejesus & Hornbaker, 1999).

## Cons

The various combinations of precision agriculture tools, the steep learning curve of these technologies, and the initial investment of each of the tools complicate farmers' decisions. Kitchen et al. (2002) identified several barriers to adopting precision agriculture. They listed obstacles to adopting precision agriculture as equipment costs, time, equipment incompatibility, technology obsolescence, needed skills, farm structure (rent vs. owned land), training and support availability, and lack of confidence in using the technology. They also indicated that they had concerns over data quality control, lack of information on purchasing new equipment and software, the need for improved data storage devices, development of remote sensing equipment, standardization of equipment and data formatting, and lack of understanding of agronomic relationships between yield and soil. This study narrows the disadvantages of using precision agriculture to economic costs and risks, skills, time, technological changes and upgrades, and support.

Swinton, Marsh, and Ahmad (1997) identified through focus groups that farmers felt that they were overwhelmed with the initial costs of precision agriculture technologies, particularly technologies that change rapidly. To adopt and use these technologies, not only do agricultural producers have to make large financial investments, but also have to invest time and effort in learning new skills. Farmers must learn to use GIS software, integrate GPS tools into existing farming implements, and understand data associated with mapping, soil quality, topography, yield variance, and crop health. Farmers must dedicate time to adjust the technologies to fit equipment and troubleshoot the technologies, as needed. This time commitment creates indirect costs of delays and missing production work. Other concerns identified were unexpected costs in upgrades of equipment and software and the incompatibility of equipment and software (Swinton et al., 1997).

Precision agriculture requires large investments in capital, time, and learning. While there is an expectation of cost effectiveness and profitability, quantifying these assets is not easily done (Swinton et al., 1997). Additionally, there is uncertainty about the cost of precision agriculture technology upgrades. This research uses investments in capital, time, and learning and hardware and software incompatibility as disadvantages of precision agriculture. The theoretical underpinnings of the TTM suggest that the perceived disadvantages (or cons) decrease in each progression to a new stage (Marshall & Biddle, 2001; Reed, 1994).

## Decisional Balance, Stage of Change, and Intention to Use Precision Agriculture

The theory of planned behavior (Fishbein & Ajzen, 1975) indicates that attitudes predict intentions, and intentions predict behavior. Stage of change is composed of attitudes and beliefs toward making a behavioral change. The stage of change is an indication of intention to behavioral change. The TTM is used to identify individuals' stage of change by using processes of change which are influenced by the decisional balance.

Decisional balance, defined as the decision making process (Janis & Mann, 1977), consists of the individuals' perceptions of the benefits and disadvantages of using the technology. In the earlier stages of change, the disadvantages outweigh the benefits of using the technology. In the later stages, the benefits outweigh the disadvantages. It is in the middle stages where the benefits and disadvantages intersect. Because the decisional balance is made up of perceptions and attitudes, the decisional balance will predict the stage of change, a continuous measure. Additionally, the pros will be positively correlated with stage of change and the cons will be negatively correlated with the stage of change.

H1a: Decisional balance predicts stage of change.

H1b: Pros are positively correlated with stage of change.

H1c: Cons are negatively correlated with stage of change.

## Factors that Influence Decisional Balance and Stage of Change

Using some aspects of the Diffusion of Innovation (Rogers, 1983) theory, Vanclay (1992), a rural sociologist, identified ten barriers to farmers' adopting new technologies: complexity, divisibility, congruence, economic, risk and uncertainty, conflicting information, implementation economic costs, implementation intellectual costs, loss of flexibility, and physical and social infrastructure. Even though economic benefit seems to be the deciding factor for sustained use of precision agricultural technologies, other reasons, such as attitudes toward the technologies, may affect adoption (Cochrane, 1993). The decisional balance is influenced by the individuals' perceptions of the technology. These perceptions include the perceived value of the technology (Armenakis et al., 1993), its relative advantage over the current practice (Rogers, 1995), its appropriateness for the operation (Armenakis et al., 1993), its compatibility within the operation, and the perception of complexity of the technology

(Rogers, 1995). During the first stage, individuals become aware of the technology and in the second stage, individuals psychologically develop perceptions about the technology.

### Perceived Compatibility of Precision Agriculture with Existing Farming Operations and Practices

Attitudes toward compatibility and appropriateness of an innovation with existing operations and its ability to meet the needs and goals of potential adopters are also important during the decision process (Armenakis & Harris, 2002; Rogers, 1995). While an innovation may have value and offer new options, it must also be appropriate for the individuals who are considering it as a change (Armenakis & Harris, 2002; Armenakis et al., 1993). Compatibility is a belief that the technology is compatible with existing practices, values, and beliefs (Coch & French, 1948; Rogers, 1995). Researchers in the IS field have found that ISs compatible with the operations and management of organizations affected the adoption of ISs (Moore & Benbasat, 1991). The more the technology is perceived to be compatible with current farm and management practices, the higher the likelihood that a farmer will adopt the technology.

H2a: The perceived compatibility of precision agriculture with existing farming operations and practices positively influences stage of change.

Precision agriculture allows for detailed information about farming operations, field characteristics, and yield information which has not been available in traditional farming (Adrian et al., 2004; Bouma et al., 1999; Lowenberg-DeBoer, 1996; Olson, 1998; Sonka, 1998). Using precision agriculture technologies means that farmers may look at their decision-making processes differently. They may begin to consider making changes to the way they plant or the way they apply chemicals. More information available to farmers means that they have more decisions to make in their operations. If having more information allows farmers to meet their goals, they will find that precision agriculture provides more benefit. Individuals who view a technology as compatible with their operations and goals, will more likely see it as useful and recognize its benefits (Chau & Hu, 2002). If farmers perceive that precision agriculture is compatible with their operations and practices, then they will perceive that precision agriculture is beneficial to them. Thus, farmers who perceive precision agriculture as compatibility with their operations will view the decisional balance at a higher level than those who perceive that precision agriculture as not being compatible with their operations and practices.

H2b: The perceived compatibility of precision agriculture with existing farming operations and practices positively influences decisional balance.

Perceived Ease of Use

Research has shown that perceptions of the complexity of information technologies in organizations affect individuals' adoption and use of computer technologies (Chau, 2001; Davis, 1989; Orr, Allen, & Poindexter, 2001; Rainer & Miller, 1996). Rogers (1995) defined the perceived complexity of an innovation as “the degree to which an innovation is perceived as relatively difficult to understand and use” (pg. 242). The theoretical assumption is that those innovations that are easier to use will have a higher acceptance rate than similar innovations that are more difficult to use. Davis (1989) identified “ease of use” as the degree of using an innovation being free of effort. He used the perception of ease of use as a factor synonymous with complexity and found that the perception of ease of use was an important determinant of acceptance of two software packages.

IS research has shown mixed results on whether complexity directly mediates the adoption of information technologies. Some studies have found that ease of use does influence the perception of usefulness (Davis, 1989) or relative advantage (Chau, 2001; Davis, 1989; Igbaria & Iivari, 1995). Therefore, ease of use indirectly affects the adoption of technologies. Individuals who view a technology as easy to use will more than likely perceive the technology as useful and beneficial. Producers who perceive precision agriculture as easy to use will view the pros at a higher level because they view the technology as beneficial. Additionally, producers who view precision agriculture as easy to use will not view the disadvantages negatively as those who view the technology as complex. Thus, farmers who perceive precision agriculture as easy to use will view the decisional balance at higher levels than farmers who view the technologies as complex.

H3a: The perceived ease of use of precision agriculture technologies positively influences decisional balance.

Farmers who find working with precision agriculture as easy to use may find that these tools are compatible with the way they work, manage, and farm. These farmers may have already developed skills in working with information technologies that help them see the tools as easy. For example, if these farmers have previously sought information technologies to assist in managing their farms, then they may have the proclivity to use these tools. Therefore, it is hypothesized that those farmers who perceive these technologies as easy to use will perceive that the precision agriculture is compatible with the way the work, farm, and manage.

H3b: The perceived ease of use of precision agriculture technologies positively influences perceived compatibility.

## Precision Agriculture Self-efficacy

There is a little research correlating the psychological characteristics of farmers and their acceptance of new technologies and practices (Adesina & Baidu-Forson, 1995). Rogers (1995) and Armenakis et al. (1993) argued that the characteristics of potential adopters are important in understanding individuals' acceptance of new technologies. Understanding the psychological characteristics of farmers who are ready to adopt and accept these technologies may help change agents target their efforts in demonstrating the technologies' benefits.

Self-efficacy, a social-cognitive construct, is the belief that one has the capability of performing a task (Bandura, 1986). Self-efficacy is prevalent in change, innovation (Armenakis et al., 1993; Bandura, 1986; Rogers, 1995), and IS literature (Compeau & Higgins, 1995; Davis, 1989; Milbrath & Kinzie, 2000; Necessary &

Parish, 1996; Rainer & Miller, 1996). The attitude of having the ability to learn and use technology influences the perception of usefulness since the expectations of the technology are derived from how well one can use the technology and is motivated to use the technology (Compeau & Higgins, 1995; Igbaria & Iivari, 1995). IS research has shown that computer self-efficacy affects computer usage, perceived ease of use, and perceived usefulness (Chau, 2001; Compeau & Higgins, 1995; Davis, 1989; Igbaria & Iivari, 1995). Farmers' self-efficacy has not been studied in the adoption and use of precision agriculture technology.

The TTM, the IDPM, and the CRCM posit that self-efficacy positively influences acceptance of change (Armenakis et al., 1993; Armitage et al., 2004; DiClemente, Prochaska, & Gibertini, 1985; Rogers, 1995). IS research shows that attitudes toward IS, particularly individuals' perceptions of capabilities and beliefs that they can learn to use the technology (Compeau & Higgins, 1995; Necessary & Parish, 1996; Rainer & Miller, 1996), affect whether they will adopt the technology (Adesina & Baidu-Forson, 1995; Davis, 1989; Milbrath & Kinzie, 2000). Armitage et al. (2004) found that self-efficacy predicts the intention and acceptance of behavioral change. Additionally, self-efficacy mediates the stage of change (DiClemente et al., 1985; Marshall & Biddle, 2001). If producers are confident that they can use and learn precision agriculture technologies, they will more likely adopt them. As individuals become more knowledgeable about the technology, they will become more confident in their ability to use the technology, and they will move through the stages of change (DiClemente et al., 1985).

H4a: Precision agriculture self-efficacy positively influences stage of change.

Self-efficacy plays an important role in influencing motivation and behavior (Bandura, 1986; Gist, 1987). Igbaria & Ivaria (1995) maintained that the perceived usefulness construct, developed by Davis (1989), serves as a measurement of motivation. Igbaria & Ivaria (1995) explained that individuals tend to "undertake behaviors that they believe will help them perform their job better". Self-efficacy affects motivations in that individuals who feel that they are not capable of using a technology may not feel very motivated in recognizing the technology's benefits. Conversely, those who feel that they are very capable of using a technology may also be motivated in recognizing the benefits of the technology. The perceived advantages of precision agriculture technologies serve as the motivational factors that help prompt individuals to adopt the technologies. Producers who have high levels of precision agriculture self-efficacy will also be able to recognize and see the technology as beneficial. By realizing the benefits, they will also have high levels of decisional balance.

H4b: Precision agriculture self-efficacy positively influences level of decisional balance.

While the technologies' usability is an important driver of the perceived ease of use of technologies, individual characteristics affect the perception of ease of use. Venkatesh (2000) found that computer self-efficacy plays a significant role in individuals' perceptions of ease of use of computer technologies. Precision agriculture technology requires a set of skills that are somewhat different than the skills used in traditional farming. The GIS tools can be complicated, particularly in integrating the data and developing management zones. One study found that confidence in using precision agriculture tools affected the intention to use precision agriculture (Adrian et al., 2005). Even though producers may believe that precision agriculture technologies are beneficial, they may feel that they do not have the ability to use the technology. Conversely, those who have higher levels of precision agriculture self-efficacy will more likely find precision agriculture technologies as easy to use. Therefore, it is hypothesized that the higher levels of precision agriculture self-efficacy will positively influence perceived ease of use.

H4c: Precision agriculture self-efficacy positively influences perceived ease of use.

Communications Behaviors

Rogers (1995) indicated that communication behaviors were related to innovativeness. Early adopters have more change agent contact, have greater exposure to mass media, have greater exposure to interpersonal communication channels, seek information about innovations more aggressively, and have greater knowledge of innovations. However, the first stage of the TTM is when the individual has no intention of adopting a new technology. Therefore, individuals' characteristics, such as their communications behavior, influence the adopters' readiness to change and these characteristics can also affect their processes of change.

Rogers (1995) also suggested that while mass media can be effective in the diffusion of simple innovations, interpersonal communications may play a greater role in the adoption of complex technologies. He notes that having contact with change agents will influence the knowledge about new technologies and are important in diffusing the adoption of complex technologies. Daberkow and McBride (2003) found that having access to information and contact with change agents, such as Cooperative Extension agents and university faculty, influences the adoption of precision agricultural technologies

Rogers (1995) also indicated that early adopters of innovations are more venturesome and will seek out information for new ideas. He postulates that early adopters have greater abilities to deal with abstraction, risks, and uncertainty. Those who have more information may feel they are more confident in using new technologies. Individuals' confidence in their ability to perform tasks is influenced by second-hand information (Ajzen & Madden, 1986).

Those who seek more information through various communication methods may have greater self-efficacy than those who do not seek additional information. Communications behaviors will influence precision agriculture self-efficacy. Finding information on the Internet provides producers with vast amount of information, not always available through local sources. Those who seek more information through various communication channels, such as the Internet, mass media, and change agents, will have greater precision agriculture self-efficacy than those who do not seek additional information.

H5a: Communications behaviors positively influence precision agriculture self-efficacy.

Some individuals seek out more information and resources by using various communication channels than others. Those who have the tendency to seek information through various means, such as the Internet and local change agents, may also find the vast amount of information available through precision agriculture technologies to be useful and compatible with the way they manage and operate their farms. Those who have the propensity to seek information through various communication channels may find that precision agriculture technologies are compatible with the way they manage the farm.

H5b: Communications behaviors positively influence perceived compatibility.

## Socioeconomic Characteristics

Rogers (1995) indicated that socioeconomic factors were related to innovativeness. For instance, more innovative individuals tend to have more formal education, have higher social status, have a greater degree of upward social mobility, and have larger units (i.e., larger farms and larger companies) than later adopters. Therefore, individuals' characteristics influence the readiness of adopters to change and these characteristics can also affect their processes of change. The precision agriculture adoption literature shows that some demographic factors, such as age, farming experience, off-farm employment, education level, farm size, and crops grown, affect the adoption of precision agriculture (Daberkow & McBride, 2003).

Farm Size

Managers of larger farms tend to be more innovative and inclined to adopt technology broadly (Batte, 2005; Rogers, 1995). Precision agriculture requires a large investment in capital, time, and learning. The fixed transactional and informational investments associated with precision agriculture technologies may prevent smaller farms from being able to invest in these technologies. Napier et al. (2000) found that farms with higher levels of gross profit were more likely to adopt precision agriculture. Larger farms are more likely able to invest large amounts of capital, time and learning new technologies than smaller farms (Batte, 2005; Batte, 2000; Lowenberg-DeBoer, 1996; Napier et al., 2000; Rogers, 1995), thus, farm size will affect stage of change.

H6: Farm size positively influences stage of change.

Education Level

Early adopters of technology tend to have higher education levels than later adopters (Batte, 2005; Hudson & Hite, 2003; Rogers, 1995). However, some research shows mixed results of the correlation between technology adoption and levels of education (Hoag, Ascough II, & Frasier, 1999; Hoag, Ascough II, & Frasier, 2000; Napier et al., 2000). It is hypothesized that education level will positively influence the stage of change of adoption of precision agriculture.

H7: Education level positively influences stage of change.

### Off-farm Employment

Researchers have found that off-farm employment correlates with the adoption of computer and Internet use (Batte, 2005; Smith, Morrison, Goe, & Kenny, 2004). The premise is that off–farm employment provides exposure to computer and Internet technologies and possibly provides skills to use the technologies. Therefore, the increased awareness and skills transfer to using computer and Internet technologies for the farm. Off-farm employment will affect stage of change.

H8: Off-farm employment positively influences stage of change.

## Summary

The decision to adopt precision agriculture technologies is not easy and is often complicated by the lack of direct evidence of economic benefit. Adoption of precision agriculture depends not only on economic reasons, but also on perceptions about the technology. These attitudes have been given little attention in precision agriculture. Understanding the adoption-decision process can help researchers develop technologies that meet the needs of the producers. These tools require technical skills and managerial skills that are somewhat different from the skills that are common in a traditional farming operation. This proposed comprehensive process model explains and predicts the stages of adoption of precision agriculture that are determined by the individuals' perceptions of the technology and their confidence in being able to use the technology. This study focuses on perceptions of precision agriculture's benefits and disadvantages, complexity, compatibility, self-efficacy, and communication behaviors. These attitudinal constructs offer a basis to develop hypotheses to test the adoption process. A summary of the hypotheses is shown in Table 1. These hypotheses are also presented graphically in Figure 2.

The model concentrates on the stage of change as described in the TTM. From a practical standpoint, the determination of stage of change can be useful to change agents so they can adjust their messages and their activities for invoking change. These activities and communications can be used to move potential adopters to the next stage. Perceived ease of use, perceived compatibility, communications behaviors, and precision agriculture self-efficacy influence the decisional balance of using precision agriculture. Decisional balance is the predictor of stage of change of precision agriculture adoption, and stage of change is a predictor of use of precision agriculture.

*Table 1*

Summary of Hypotheses

| # | Hypothesis |
|---|---|
| H1 | Decisional balance predicts stage of change. |
| H1a | Pros are positively correlated with stage of change. |
| H1b | Cons are negatively correlated with stage of change. |
| H2a | Perceived compatibility of precision agriculture with existing farming operations and practices positively influences stage of change. |
| H2b | Perceived compatibility of precision agriculture with existing farming operations and practices positively influences decisional balance. |
| H3a | Perceived ease of use of precision agriculture technologies positively influences decisional balance. |
| H3b | Perceived ease of use of precision agriculture technologies positively influences perceived compatibility. |
| H4a | Precision agriculture self-efficacy positively influences stage of change. |
| H4b | Precision agriculture self-efficacy positively influences level of decisional balance. |
| H4c | Precision agriculture self-efficacy positively influences the perceived ease of use. |
| H5a | Communications behaviors positively influence precision agriculture self-efficacy. |
| H5b | Communications behaviors positively influence perceived compatibility. |
| H6 | Farm size positively influences stage of change. |
| H7 | Education level positively influences stage of change. |
| H8: | Off-farm employment positively influences stage of change. |

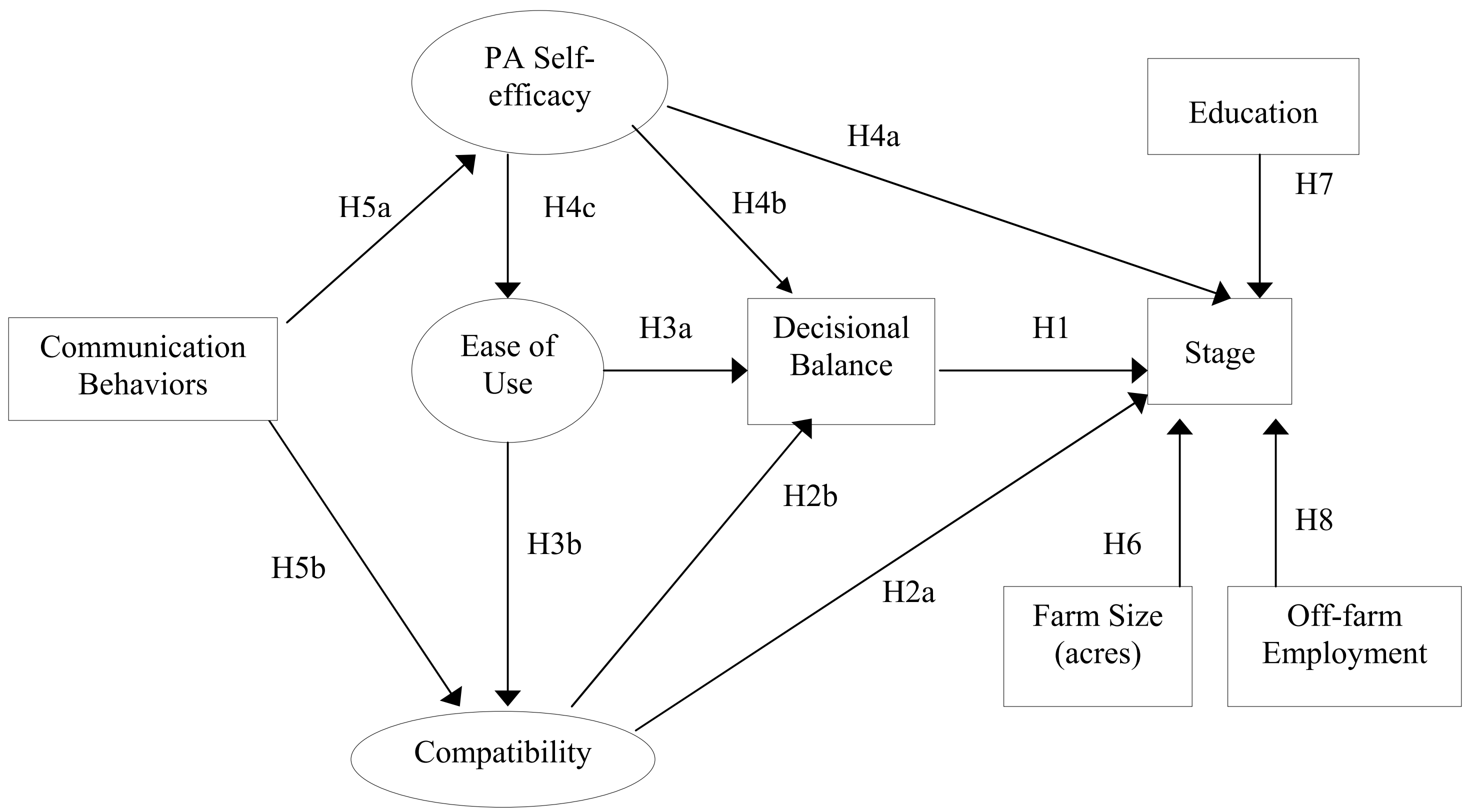


Figure 2. Structural model for stage of change in adoption of precision agriculture

# CHAPTER 3

# METHODOLOGY

The literature review chapter proposed a model for analyzing the stage of change associated with the adoption of precision agriculture using the TTM. A survey was developed to include questions pertaining to the use of precision agriculture technologies, scales for the pros and cons constructs, perceived ease of use, perceived compatibility, precision agriculture self-efficacy, communications behaviors, farm size, off-farm employment, and education level of the farmers. This survey instrument was used to collect data and empirically test the relationships of the structural model for stage of change in precision agriculture adoption shown Figure 2. The items in the questionnaire operationalized the constructs in the research model (Figure 2) with changes in wording appropriate for precision agriculture. Survey data were collected from agricultural producers in Alabama. Each step of the development and implementation of the survey instrument is described in this chapter.

## Research Protocol

Approval for this survey instrument was granted by the Institutional Review Board of Research Involving Human Subjects at Auburn University Protocol. A cover letter describing the research and explaining the rights of the survey participants was included with the survey instrument. The cover letter is included in Appendix A. The data set provided to the researcher was anonymous.

## Measure and Instrument Development

A four-page survey instrument was designed with most of these variables measured as multi-item scales. The questionnaire was reviewed by a group of agricultural researchers, Cooperative Extension specialists, and Extension field agents. Suggestions for changing the wording of particular items were made and implemented.

The questionnaire was also reviewed by the statisticians in the United States Department of Agriculture-National Agricultural Statistics Service (USDA-NASS) Alabama Statistics Office. The statisticians provided suggestions to the wording of some of the socio-economic questions. Their suggestions came from their experience in collecting survey data from this particular population. The survey was mailed to the participants and self-administered. The survey instrument is shown in Appendix B.

The decisional balance construct was developed from the advantages and disadvantages of using precision agriculture for managing agronomic and crop conditions. The scales for the pros and cons represented both cognitive and motivational factors derived from precision agriculture use research. The pros consisted of economic benefit, environment information, and information for use of management strategies. The cons consisted of investments, time, learning, effort, and risk. The scales for self-efficacy were taken from Hill, Smith, and Mann (1987). The scale for perceived ease of use was taken from the TAM (Davis, 1989) and adjusted for precision agriculture. The scale for compatibility was derived from the compatibility scale used in the Moore and Benbasat (1991) study.

## Participants' Use of Precision Agriculture Tools

Analyzing the use of different precision agriculture tools to understand adoption patterns is difficult. It is important, though, to determine which tools are being adopted. In the questionnaire, the participants were asked about intention and use of each individual tool. Use of precision agriculture tools was defined by the intention and use of each specific tool. Intention was determined by whether the tools will be used within the next two years. Usage of precision agriculture tools for managing agronomic and crop conditions was determined by whether the tools have been used within the last year or longer.

## Target Behavior

The first step in applying the TTM to behavioral change is to identify and clearly define the target behavior in the model. Because stage of change methodologies have not been used in researching the adoption of precision agriculture, ensuring that an appropriate definition of precision agriculture use and the target behavior defined in the stage of change model is essential. The target behavior is the behavior one would want to obtain in the maintenance stage. The target behavior for this study is to use of precision agriculture technologies for at least two years.

*Table 2*

Precision Agriculture Tools Used

| |
|---|
| Grid or zone soil sampling with GPS |
| Yield monitor with GPS |
| Variable rate application (fertilizer, insecticide, seeding, & defoliation) |
| Remote sensing |
| GIS (mapping software) |
| Lightbar |
| Autoguidance system (for example, auto steer equipment) |

The TTM's stage of change is a temporal dimension of readiness to change behavior. Typically, each stage represents a time period. The time dimension defined in the TTM should be appropriate for the domain of behavior being investigated (Prochaska et al., 2001). Although in most health related TTM studies the target behavioral change is sustained for six months, for this study the target behavior is defined as sustained use of precision agriculture for at least two years. Using precision agriculture for at least two years suggests that farmers have had enough time to decide whether to continue using precision tools. A period any shorter could mean that the producer is really in a trial mode and has not committed to use the technologies.

The target behavior in this study is the use of precision agriculture tools for at least two years. This researcher presented this definition of the target behavior to a group of agricultural researchers and Cooperative Extension faculty and field agents.

They agreed that this definition of precision agriculture was appropriate and that the fives stages shown in Table 3 were appropriately classified.

*Table 3*

Producers' Stages of Adoption for Precision Agriculture

| Stage | Behavior |
|---|---|
| Precontemplation | Producer has no intention of adopting precision agriculture technology. |
| Contemplation | Producer is considering adopting precision agriculture and may have even tried a precision agricultural tool, but has not yet decided to use precision agriculture. |
| Preparation | Producer has the intention of using precision agriculture within the next year. |
| Action | Producer has used precision agriculture within the last year. |
| Maintenance | Producer has used precision agriculture for two years. |

## Staging Algorithm

Researchers have used two different methods for describing the stages—a continuous scale and a categorical measure. The discrete categorical measure uses a brief, mutually exclusive set of questions that measures the five stages of change to include: precontemplation of change, contemplation of change, intention of change, action, and maintenance of the behavior. The discrete categorical approach is used to compare individuals and variables in sequential stages and usually measure with one statement for each stage. An example of a statement indicating the maintenance stage is: “I have been using precision agriculture for two or more years.”

The other method is a continuous scale which also uses separate scales for the five stages. The continuous scale uses more survey items than the discrete categorical scales. The staging algorithm produces a stage score which is an assessment of readiness to change behavior. This algorithm is anchored by the theory of reasoned action (Fishbein & Ajzen, 1975) and theory of planned behavior (Ajzen & Madden, 1986). Along the continuum, the movement from stage-to-stage is perceived to be a linear progression (Prochaksa et al., 1992) and is often used to predict intention and behavior (Marcus, Selby, Niaura, & Rossi, 1992; McConnaughy et al., 1983; Prochaksa et al., 1992). Researchers have found that other factors will influence the stage of change, such as self-efficacy (DiClemente et al., 1985; Marcus et al., 1992; Weinstein, Rothman, & Sutton, 1998).

Typically, each stage represents a time period. The TTM has been used mostly in health behavior change where a six month period is used. For this research, identifying a time period that indicates a commitment in both time and economic investments and that reflects the use in such a way that the producer can evaluate his commitment a period of two years is appropriate. A period any shorter could mean that the producer is really in a trial mode and has not committed to use the technologies.

The items used in the staging algorithm were based on the University of Rhode Island (URICA) 24-item form. The items were adjusted slightly to be appropriate for stages associated with the adoption of precision agriculture. These items were presented to a group of agricultural researchers, Cooperative Extension specialists, and Extension field agents who agreed that two years was appropriate time to define the maintenance stage and that the survey items correctly represented the stages. One item was split to include two separate items that represent an assessment of time and skills (see items 63 and 64 in Table 4.). Table 4 shows the survey items and the stage each represents.

*Table 4*

Items for Staging Algorithm

| Survey Item | Items | Stage |
|---|---|---|
| 53 | As far as I'm concerned, I do not need to use precision agriculture. | Precontemplation (non-believing ) |
| 54 | I have been using precision agriculture for a long time and I plan to continue. | Maintenance |
| 55 | I don't use precision agriculture right now and I don't care to. | Precontemplation (non- believing) |
| 56 | I am finally using precision agriculture. | Action |
| 57 | I have been successful at using precision agriculture and I plan to continue. | Maintenance |
| 58 | I am satisfied with not using precision agriculture. | Precontemplation (non- believing) |
| 59 | I have been thinking that I might want to start using precision agriculture. | Contemplation |
| 60 | I have started using precision agriculture within the last two years. | Action |
| 61 | I could use precision agriculture, but I don't plan to. | Precontemplation (non- believing) |

Table 4. Continued

| Survey Item | Items | Stage |
|---|---|---|
| 62 | Recently, I have started to use precision agriculture. | Action |
| 63 | I don’t have the time to use precision agriculture right now. | Precontemplation (believing) |
| 64 | I don’t have the skills to use precision agriculture right now. | Precontemplation (believing) |
| 65 | I have started to use precision agriculture, and I plan to continue. | Maintenance |
| 66 | I have been thinking about whether I will be able to use precision agriculture tools. | Contemplation |
| 67 | I have set aside some time to start using precision agriculture within the next year. | Preparation |
| 68 | I have managed to use precision agriculture for the last two years. | Maintenance |

Table 4. Continued

| Survey Item | Items | Stage |
|---|---|---|
| 69 | I have been thinking that I may want to begin to use precision agriculture. | Contemplation |
| 70 | I have lined up with a professional to start using precision agriculture | Preparation |
| 71 | I have completed two years of using precision agriculture. | Maintenance |
| 72 | I know that using precision agriculture is worthwhile, but I don't have time for it in the near future. | Precontemplation (believing) |
| 73 | I have been calling fellow farmers or agricultural professionals to find someone to help me start using precision agriculture. | Preparation |
| 74 | I think using precision agriculture is good, but I can't figure it into my schedule right now. | Precontemplation (believing) |
| 75 | I really think I should work on getting started with using precision agriculture within the next two years. | Contemplation |
| 76 | I am preparing to start using precision agriculture within the next year. | Preparation |
| 77 | I am aware of the importance of using precision agriculture, but I can't do it right now. | Precontemplation (believing) |

### Scoring of the Stages

The URICA short form includes subscales that measure stage of change—precontemplation (nonbelieving), precontemplation (believing), contemplation, preparation, action, and maintenance. The subscales are combined arithmetically to generate a continuous scale that can be used to assess the change. Stage of change scores for this study were calculated by summing the standardized scores for maintenance, action, preparation, and contemplation and subtracting the standardized scores for precontemplation (Marcus et al., 1992; McConnaughy et al., 1983).

## Decisional Balance

Decisional balance, proposed by Janis and Mann (1977), was used to compare the gains and losses of making a change. Decisional balance represents both cognitive and motivational aspects of decision making. Careful selection of the scale items helps ensure content validity of the construct (Nunnally, 1978). Possible scale items should be formulated by the conceptual definitions of construct (Anastasi, 1986). Following these recommendations, the possible items for the pros and cons of the decisional balance were generated from research on the adoption of precision agriculture and were pre-tested.

### Pros

The specific items for the pros of the decisional balance construct were taken from precision agriculture research that identified advantages of using precision agriculture. The perception of economic value and operational benefits is important to explain the adoption of these technologies (Batte & Arnholt, 2003; Cochrane, 1993;

Rogers, 1995). Use of precision agriculture leads to varying inputs by decreasing inputs in areas where the chemicals are not needed which leads to reduction in costs. Increasing inputs, such as chemicals, potentially means that yields will be greater in those areas, thus increasing yields is a potential advantage of using precision agriculture. Both reducing costs and increasing production yield greater profits. These three benefits have been documented in research and in the agricultural industry press as potential benefits of precision agriculture (Batte, 2000; Godwin et al., 2003).

Table 5 shows the items that represented the pros. Each item is displayed with the reference. These items were part of the questionnaire; the participants were asked to rate the importance of each statement in their decision to use or not use precision agriculture tools.

*Table 5*

Pros of Using Precision Agriculture

| Survey Item | Pros | Reference |
|---|---|---|
| | Precision agricultural tools… | |
| 78 | reduce costs. | Batte, 2000; Olson, 1998 |
| 79 | increase yields. | Batte, 2000; Godwin et al., 2003; Olson, 1998 |
| 80 | increase profits. | Batte, 2000; Godwin et al., 2003; Olson, 1998 |
| 81 | reduce chemical inputs. | Hudson & Hite, 2001; Napier et al., 2000; Olson, 1998; Wolf & Buttel, 1996 |
| 82 | allow for efficiently targeting nutrients. | Godwin et al., 2003; Hudson & Hite, 2001; Olson, 1998; Rejesus & Hornbaker, 1999 |
| 83 | provide environmental information. | Godwin et al., 2003; Hudson & Hite, 2001; Olson, 1998; Rejesus & Hornbaker, 1999; Wolf & Buttel, 1996 |
| 84 | allow me to acquire and analyze field data. | Godwin et al., 2003; Kitchen et al., 2002; Olson, 1998 |

Table 5 Continued

| Survey Item | Pros | Reference |
|---|---|---|
| | Precision agricultural tools… | |
| 85 | increase my cropland's value. | Napier et al., 2000 |
| 86 | increase the amount of cropland I can manage. | Olson, 1998 |
| 87 | increase attention to management. | Atherton, et al. 1999; Godwin et al., 2003; Hudson & Hite, 2001; Kitchen et al., 2002; Olson, 1998 |
| 88 | decrease financial risks. | Godwin et al., 2003; Olson, 1998 |
| 89 | collect information on the variability within fields. | Godwin et al., 2003; Kitchen et al., 2002; Napier et al., 2000; Olson, 1998 |
| 90 | reduce farm labor. | Lowenberg-DeBoer & Swinton, 1997 |
| 91 | manage labor resources. | Lowenberg-DeBoer & Swinton, 1997 |
| 92 | allow me to create my own field experiments. | Swinton et al., 1997 |

Cons

The items for the cons of the decisional balance were developed from research studies which defined these as the potential disadvantages of using precision agriculture. The items representing these costs were included in the cons construct. Table 6 shows the items that were presented as cons construct. Each item is displayed with the reference. These items were part of the questionnaire; the participants were asked to rate the importance of each statement in their decision to use or not use precision agriculture tools.

*Table 6*

Cons of Using Precision Agriculture

| Survey Item | Cons | Reference |
|---|---|---|
| | Precision agricultural tools… | |
| 93 | are expensive. | Godwin et al., 2003; Kitchen et al., 2002; Olson, 1998; Swinton et al., 1997 |
| 94 | require me to have skills that I do not have. | Kitchen et al., 2002 |
| 95 | require me to get training in order to use these tools. | Godwin et al., 2003; Kitchen et al., 2002; Olson, 1998; Swinton et al., 1997 |
| 96 | provide data that are difficult to interpret. | Kitchen et al., 2002 |

Table 6 Continued

| Survey Item | Cons | Reference |
|---|---|---|
| 97 | are dependent on machinery. | Kitchen et al., 2002; Olson, 1998; Swinton et al., 1997 |
| 98 | require a large farm to be cost effective. | Godwin et al., 2003; Napier et al., 2000 |
| 99 | require me to find support sources for advice. | Godwin et al., 2003; Kitchen et al., 2002; Olson, 1998; Swinton et al., 1997 |
| 100 | require an understanding of agronomy. | Kitchen et al., 2002 |
| 101 | are time consuming. | Kitchen et al., 2002 |
| 102 | are difficult to integrate into traditional farming. | Kitchen et al., 2002 |
| 103 | are difficult to keep abreast of new and upgrade technologies. | Kitchen et al., 2002 |
| 104 | are difficult to use. | Kitchen et al., 2002 |
| 105 | are expensive to keep up-to-date with the newest technologies. | Kitchen et al., 2002 |

## Perceived Ease of Use

Davis (1989) defined perceived ease of use as a construct representing the degree for which a technology would be free of effort. These items were adjusted to represent the level of complexity of precision agriculture tools. These seven items used a 5 point Likert scale, "strongly disagree" to "strongly agree", and are listed in Table 7.

*Table 7*

Ease of Use Items

| Item | Survey Item |
| --- | --- |
| Learning to operate precision agriculture tools is easy for me. | 46 |
| I find it is easy to get precision agriculture tools to do what I want it to do. | 47 |
| It is easy for me to remember how to perform tasks using precision agriculture tools. | 48 |
| My interaction with precision agriculture tools is clear and understandable. | 49 |
| I find precision agriculture tools to be flexible to interact with. | 50 |
| It is easy for me to become skillful at using precision agriculture tools. | 51 |
| I find precision agriculture tools easy to use. | 52 |

## Perceived Compatibility of Precision Agriculture with Existing Operations and Practices

Perceptions about compatibility of precision agriculture with existing operations and practices were represented by items from the Moore and Benbasat (1991) study. The four items were adapted to be appropriate for precision agriculture technologies, using a 5 point Likert scale, "strongly disagree" to "strongly agree", and are listed in Table 8.

*Table 8*

Perceived Compatibility Items

| Item | Survey Item |
|---|---|
| Precision agriculture is compatible with all aspects of my farm operation. | 42 |
| Precision agriculture is completely compatible with my current farming situation. | 43 |
| Using precision agriculture fits well with the way I like to farm. | 44 |
| Using precision agriculture fits with my farming style. | 45 |

## Precision Agriculture Self-efficacy

The measurement of self-efficacy, a social-cognitive belief that one has the capability of implementing the new technology, was adapted from the Hill, Smith, and Mann (1987) study. Self-efficacy in producers' abilities has not been studied in the adoption and use of precision agriculture technology, though self-efficacy can be a predictor of technology use. The items used a 5 point Likert scale, "strongly disagree" to "strongly agree" to measure precision agriculture efficacy. The self-efficacy items are shown in Table 9. Because the wording of all of these items is negatively stated, the items were reverse coded.

*Table 9*

Precision Agriculture Self-efficacy Items

| Item | Survey Item |
|---|---|
| I will never understand how to precision agriculture tools. | 38 |
| Only a few experts really understand how precision agriculture tools work. | 39 |
| It is extremely difficult to learn how to use precision agriculture tools. | 40 |
| Precision agriculture errors are difficult to fix. | 41 |

## Communications Behaviors

Rogers (1995) indicated that exposure to information was related to innovativeness. The items used for exposure to information were measured with two different sets of items that measured the frequency and importance of sources of information for agricultural practice. The instructions directed the survey participants to rank the frequency of using each source for production agricultural practices, production, and management. The scale ranged from “not at all” to “very frequent” on a 5 point Likert scale. They were also asked to rank the importance of each source for production agricultural practices, production, and management. The scales ranged from “not at all important” to “extremely important” on a 5 point Likert scale. The sources are shown in Table 10. The assumption is that the more different items that were ranked high in importance and in frequency, then the more innovative a producer may be. Thus, the producers who used these sources were more likely to adopt and understand the benefits of precision agriculture.

*Table 10*

Sources of Information for Agricultural Production, Practices, and Management

| Item | Survey Item |
|---|---|
| University Extension Agent, Specialist, or Representative | 4 and 14 |
| University Extension/Research Newsletters, Publications | 5 and 15 |
| Other farmers | 6 and 16 |
| Agribusiness Vendor | 7 and 17 |
| Production Magazine | 8 and 18 |
| TV News | 9 and 19 |
| Radio | 10 and 20 |
| Newspaper | 11 and 21 |
| Internet Resource | 12 and 22 |
| Email Group/List | 13 and 23 |

Farm Size, Educational Level, and Off-Farm Employment

Farm size was measured with two different items. One item asked about how many acres the producers operate and the next item asked the amount of sales of the farming operation (Napier et al., 2000). Sales were broken into 6 categories: Less than $10,000; $10,000 to $24,999; $25,000 to $49,999; $50,000 to $99,999; $100,000 to $249,999; and more than $250,000.

Education level was measured as having some high school, high school degree or GED, trade school, some college, a college degree, and a graduate degree. Off-farm employment was measured with a single yes/no answer to the question, "Are you employed outside the farm?"

## Knowledge of Precision Agriculture

While the focus of this study is on the adoption of precision agriculture, those participants who know nothing or very little about precision agriculture will not be able to rank the importance of these tools. Therefore, one item for each tool was asked about the participant's knowledge of that tool. Respondents ranked their level of knowledge of each of the tools. The ranking included six options: Never heard of this tool; Heard of this tool, but do not know what it is; Heard about this tool and know a little about it; Know what this tool is, but do not know how it is used or how to use it; Know what this tool is and how it is used, but do not know how to use it; and Know what this tool is, how it is used, and how to use it.

## Participants

Survey data were collected from agricultural producers in Alabama who have more than 50 acres of row crops. The sample for this study is a USDA-NASS list of agricultural producers. The population of farmers with more than 50 acres of row crops is 2,805 farms. To ensure the confidentiality of all participants, the USDA-NASS Alabama Statistics Office administered the survey and arranged all correspondence with participants.

## Survey Procedure

The questionnaire was reviewed by a group of agricultural researchers, Cooperative Extension specialists, Extension field agents, and statisticians with the Alabama Agricultural Statistics Office. 1,117 surveys were mailed to farmers with more than 50 acres in row crop production. Along with the survey, a letter signed by this researcher explaining that the responses would be anonymous (see Appendix A) was included in the mailing. The survey was four pages long, included 108 questions. All questions were written as single items, with the exception of the third question on the first page which had 6 items. The survey was addressed to be returned to USDA-NASS (see Appendix B).

## Sampling Methods

The sample for this study was the USDA-NASS list of agricultural producers in Alabama. This list is continually updated by obtaining current information from a variety of local and state sources. Crop acreages, livestock and poultry inventories, economic data, and various operator control data characteristics are maintained for each farm operator on the list.

The USDA-NASS Alabama Statistics Office randomly selected participants who operate more than 50 acres of row crop or grains. Because precision agriculture requires a significant amount of investment, 50 acres was used as a minimum cut-off for the sample.

Participant selection and survey administration were completed by the USDA-NASS Alabama Statistics Office. Farmers were mailed using a self-administered survey instrument. A postcard reminder was sent to those farmers who did not respond after two weeks of the questionnaire being mailed. The surveys were addressed to be returned to USDA-NASS Alabama Statistics Office. After a few weeks, the Alabama Statistics Office called the farmers who had not responded to the survey and encouraged them to complete the survey. An additional survey was sent to respondents, if they needed it.

## Plan of Analysis

This section provides a summary of the statistical and analytical tools used to analyze the data generated from the survey method. The statistical tools used to analyze the data were descriptive statistics, confirmatory factor analysis, and structural equation modeling.

## Missing Data

Mean substitution was used to replace missing data. The general rule of thumb is that mean substitution is appropriate when less than 10 percent of the data are missing (Roth, 1994). In his study, Downey (1998) also found that mean substitution provided very good representation of the original data when there is less than 20 percent of the data missing. Thus, the missing data were replaced with the mean of the item using the SPSS replacing mean function.

## Descriptive Statistics

The first step in analyzing the results of the survey collection was the examination of the demographic data and usage of the precision agriculture tools. Variables examined were off-farm employment, educational level, farm size by farm sales, farm size by acreage managed, communications behaviors, and levels of use for each precision agriculture tool. Additionally, a comparison of the acreage managed variable was conducted for non-respondents and respondents. The non-response data was provided by USDA-NASS.

## Confirmatory Factor Analysis

The second step involved in analyzing the data was to use confirmatory factor analysis to evaluate construct validity and reliability of the scales. Construct validity was examined using convergent and discriminant validity of the constructs. Convergent validity represents how well the items load on their respective factors and is evaluated by the statistical significance as expressed by the critical ratio of each loading (Anderson & Gerbing, 1988; Bollen, 1989). The critical ratio is calculated from the regression weight divided by the standard error. Convergent validity is considered to be satisfactory when the items load on their respective constructs and each loading is greater than .5 and is statistically significant. When the critical ratio is greater than 1.96 for a given item, then the item is significant ($p < .05$) (Anderson & Gerbing, 1988; Bollen, 1989).

Discriminant validity is inferred when measures of each construct converge on their respective true scores that are unique from the loading of other constructs (Churchill, 1979). Discriminant validity was assessed for each of the constructs by comparing the $\chi^2$ difference between a constrained model and a model where the constructs were allow to freely covary for each pair of constructs in the model

(Anderson & Gerbing, 1988). This test was performed separately for the stage of change and the decisional balance constructs.

Additionally, Cronbach's alpha statistics were utilized to test for the internal consistency, also called reliability, of each stage of change subscale and perceived ease of use, perceived compatibility and precision agriculture self-efficacy scales. The Cronbach statistic ranges from zero to one and values close to one indicate excellent internal consistency. Values for the Cronbach estimates should be above .70 to achieve fair internal consistency, .80 to achieve good internal consistency, and .90 to achieve excellent internal consistency (Cicchetti, 1994).

For each construct, the assessment of overall fit, or goodness of fit, was conducted using several goodness of fit measures (Hu & Bentler, 1999). The most common goodness of fit measure is the $\chi^2$ statistic. A non-significant $\chi^2$, when the p-value is greater than .05, indicates a good fit. While this is the only goodness of fit measure that indicates significance, a non-significant $\chi^2$ is implausible because it is so sensitive to sample size and the number of indicators in the model (Browne & Mels, 1992). Therefore, other measures were also used to assess an adequate fit.

An alternative to the $\chi^2$ statistic is the $\chi^2$ to degrees of freedom ratio. The ratio should approach the value of one. Several rules of thumb are recommended as the upper limit to indicate an acceptable fit. Recommended values range from a low-end of two (Byrne, 2001) to five (Wheaton, Muthen, Alwin, & Summers, 1977). Some IS researchers have used a value of three to indicate a satisfactory fit (Kettinger, Lee, & Lee, 1995; Segars & Grover, 1993).

RMSEA, another fit measure, is the average size of the fitted residuals per degrees of freedom. RMSEA is one of the fit indices that is affected by sample size. Values of zero indicate a perfect fit and values of .05 or less indicate a close fit, values of .08 indicate an adequate fit, and values of .10 or greater are not acceptable (Browne & Cudeck, 1993).

The other goodness of fit indices used are Comparative Fit Index (CFI), Normed Fit Index (NFI), and Tucker-Lewis Index (TLI). CFI, also known as the Bentler Comparative Fit Index, compares the existing model fit with a null model which assumes the latent variables in the model are uncorrelated. The CFI is less sensitive to sample sizes than other goodness of fit indices. CFI penalizes for the number of parameters in the model. Values range from zero to one. A value of one indicates a perfect fit, with greater than .90 indicate an adequate fit model and values exceeding .95 indicate a good fit (Hu & Bentler, 1999).

The NFI reflects the proportion by which the researcher's model improves fit compared to the null model. One disadvantage of using NFI is that it increases as parameters are added. Values greater than .90 indicate an adequate fit and values greater than .95 indicate a good fit.

The TLI is similar to the NFI, but penalizes for model complexity. A value of 1 indicates a perfect fit. Values greater than .90 indicate an adequate fit and values greater than .95 indicate a good fit (Hu & Bentler, 1999).

## Decisional Balance and Stage Correlations

It is hypothesized that the stage of changes influences decisional balance. As the decisional balance increases, the stage score should also increase. The components of decisional balance, the pros and cons, were also analyzed for correlation with stage of change.

## Structural Equation Modeling

The third step in the analysis was to evaluate the hypothesized structural equation model by using Analysis of Moment Structures (AMOS) which simultaneously estimates the model, including latent and observed variables, exogenous and endogenous variables, and the paths to these variables. The overall fit and explanatory power of the model was examined. The relative strength and significance of the individual paths were also evaluated.

The assessment of overall fit, or goodness of fit, was conducted using several goodness of fit measures (Hu & Bentler, 1999). The goodness of fit measures used were the $\chi^2$ statistic, $\chi^2$ to degrees of freedom ratio, RMSEA, CFI, NFI, and TLI.

The final step in the analysis was to test the hypotheses. Each of the paths of the structural model was accessed by evaluating the significance of the path ($p < .05$). Additionally, the relative strength of each of the paths was examined by evaluating the standardized regression weights. The hypotheses as described in Chapter 2, Table 1 were evaluated.

## Summary

The purpose of this research is to create a model that describes, explains, and predicts the stage of change associated with the precision agriculture adoption-decision process, and ultimately, use of precision agriculture tools. Confirmatory factor analysis was used to assess the convergent and discriminant validity of the constructs. The proposed model, Figure 2, and the hypotheses, Table 1, were tested using structural equation modeling.

# CHAPTER 4

# RESULTS

This chapter presents the results of statistical analyses. Results presented are descriptive statistics, confirmatory factor analysis, path analysis using structural equation modeling, and hypotheses testing.

## Descriptive Statistics

The Alabama Agricultural Statistics Office randomly sampled 1,177 farmers from a population of 2,805 farms with more than 50 acres of row crops. The average size farm in the sampled population was 491 row crop acres. The average size farm that responded to the survey was 495 row crop acres. Thus, there was no significant difference in the respondents' and non-respondents' farm size acreage.

Out of 587 (50% response rate) responses, 301 of these farmers indicated that at least one of the targeted row crops were grown during the 2005 crop year. The remaining 286 surveys that were returned, but were labeled as non-usable because the respondents no longer grow row crops. They are either retired and no longer in business, or they are still actively farming but no longer grow row crops. In other words, they may be growing other crops (i.e. hay) and/or raising cattle.  Out of the 301 surveys from farmers who indicated that they grew at least one row crop, 26 of these farmers indicated that they grew fewer than 50 acres in row crops. Of the remaining

275 surveys, 14 had only a few items marked so these were also marked as unusable, leaving 261 usable surveys. These 261 surveys represent 22 percent of the sample and roughly 10 percent of the population.

## Acres Managed

Of the 261 usable surveys, the average farm size was 495 acres with a standard deviation of 524. The minimum farm size was 50 acres and the maximum farm size was 3,100 acres. These surveys represented 129,180 acres of row crop land in Alabama. Of these farms, 147 farms grow corn totaling 24,051 acres; 138 farms grow cotton totaling 56,514 cotton acres; 98 farms grow peanuts totaling 23,491 peanut acres; 98 farms grow soybeans totaling 20,033 acres; and 45 farms grow 4,809 acres. A summary of the acres represented in the survey is shown in Table 11.

*Table 11*

Number of Acres Managed

| | Number of Farms | Mean (Acres) | Standard Deviation | Minimum (Acres) | Maximum (Acres) | Total Acres Represented in Study | Total in Alabama (Acres) |
|---|---|---|---|---|---|---|---|
| Total Acres | 261 | 495 | 524 | 50 | 3,100 | 129,180 | |
| Corn* | 147 | 164 | 174 | 5 | 1,000 | 24,051 | 220,000 |
| Cotton* | 138 | 410 | 409 | 10 | 2,450 | 56,514 | 550,000 |
| Peanuts* | 98 | 240 | 244 | 1 | 1,700 | 23,491 | 200,000 |
| Soybeans* | 98 | 204 | 212 | 5 | 1,000 | 20,033 | 210,000 |
| Wheat* | 45 | 107 | 99 | 4 | 475 | 4,809 | 120,000 |

* Mean, Standard Deviation, Minimum, and Maximum estimates do not include farms reporting 0 (zero) acres in crop.

### Value of Sales

Another measure of farm size is the value of sales. 56 percent of the survey participants indicated that farm sales exceed $100,000; 3.4 percent noted that they have sales of less than $10,000 and 5 percent of the participants did not answer the question. The frequency of responses to the sales value item is shown in Table 12.

*Table 12*

Farm Size Using Value of Sale Responses

| Sales Level | Respondents (Number) | Respondents (Percent) |
|---|---|---|
| Less than $10,000 | 9 | 3.4 |
| $10,000 to $24,999 | 22 | 8.4 |
| $25,000 to $49,999 | 34 | 13.7 |
| $50,000 to $99,999 | 37 | 14.2 |
| $100,000 to $249,999 | 81 | 29.5 |
| More than $250,000 | 77 | 26.4 |
| No Response | 13 | 5 |

## Farm Status and Educational Level

Of the 261 survey respondents, 68 percent of the respondents indicated that they farm full-time. 30.7 percent of the respondents are employed off-the-farm. A summary of farming status is shown in Table 13. 31.1 percent of the respondents had trade school or some college and 26.4 percent of the respondents had a college or graduate degree. A summary of the education level of the respondents is shown in Table 13.

*Table 13*

Farm Status and Educational Level

| Farm Status | Respondents (Number) | Respondents (Percent) |
|---|---|---|
| Farm Part-time | 83 | 31.8 |
| Full Time | 177 | 67.8 |
| Off farm employment | 80 | 30.7 |
| Do not work off the farm | 181 | 69.3 |
| **Educational Level** | | |
| Some high school | 15 | 5.7 |
| High school or GED | 96 | 36.8 |
| Trade school | 19 | 11.1 |
| Some college | 52 | 19.9 |
| 4-year college | 48 | 18.4 |
| Graduate/professional school | 21 | 8.0 |

## Knowledge, and Use of Precision Agriculture Tools

Table 14 shows the responses associated with intention and use of precision agriculture tools. About 22 percent of the respondents indicated that they have used at least one precision agriculture tool. Another 23 percent indicated that they intend to use at least one precision agriculture tool in the future.

This result indicates that Alabama is still in the early stages of adoption, which is behind in the adoption rates of others in the United States (Daberkow & McBride, 2003; Isik et al., 2000). A recent survey of Ohio farmers indicated 32 of the farmers has adopted at least one precision agriculture tool (Batte, 2005).

While some studies have indicated that the yield monitor is the tool most often adopted (Precision Ag, 2005; Swinton et al., 1997), in this study, the variable rate application technologies were adopted by more farmers than any other tool. The least known tool was the light bar guidance system.

*Table 14*

Intention and Use of Precision Agriculture Tools

| | VRA | Grid Sampling | Yield Monitor | Lightbar | Auto-guidance | GIS | Remote Sensing |
|---|---|---|---|---|---|---|---|
| Mean | 1.60 | 1.38 | 1.27 | 1.23 | 1.20 | 1.11 | .99 |
| Standard Deviation | 1.331 | 1.179 | 1.006 | 1.331 | 1.043 | 1.015 | .932 |
| Statement | Frequency of Response | | | | | | |
| I have never heard of this tool. | 36 | 45 | 38 | 80 | 50 | 63 | 74 |
| I have at least some knowledge of this tool, but I do not intend to use this tool on my farm in the foreseeable future. | 135 | 144 | 164 | 120 | 158 | 151 | 142 |
| I intend to use this tool in the foreseeable future, but not within the next year. | 47 | 41 | 38 | 26 | 35 | 26 | 28 |
| I intend to use this tool within the next year. | 20 | 15 | 19 | 11 | 12 | 18 | 10 |
| I have been using this tool less than 2 years. | 12 | 17 | 3 | 17 | 5 | 6 | 4 |
| I have been using this tool for more than 2 years. | 19 | 7 | 7 | 12 | 8 | 4 | 3 |

## Communications Behaviors

In this sample, most farmers cited Extension and University staff, Extension publications, other farmers, and other vendors as sources that they frequently or very frequently used. The survey participants also rated these same sources as important and very important. Radio, Internet, and email are the sources cited the least as frequently used sources for agricultural production information. Table 15 shows the number of participants selecting how frequently they used the various sources. Table 16 shows how farmers rated the importance of these sources.

These two methods of rating sources yielded similar results. For simplicity, a communications behavior score was created by taking the mean of the frequently used source items. An individual who uses several sources frequently would have a higher score than someone who uses few sources. The premise is that those who are exposed to many communication channels have more information to make decisions.

*Table 15*

Mean, Standard Deviation, and Frequency of Using Sources for Agricultural Production, Practices, and Management

| | Extension / University | Extension Publication | Other Farmers | Vendors | Production Magazines | TV | Radio | Newspapers | Internet | Email |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 2.98 | 3.19 | 3.76 | 3.39 | 3.17 | 2.18 | 1.91 | 2.13 | 2.17 | 1.65 |
| Standard Deviation | 1.201 | 1.188 | 1.058 | 1.198 | 1.120 | 1.143 | 1.052 | 1.122 | 1.251 | 1.011 |
| Rating | Frequency of Response | | | | | | | | | |
| Not at all | 39 | 32 | 11 | 28 | 27 | 94 | 123 | 97 | 114 | 163 |
| Infrequently | 51 | 39 | 25 | 27 | 38 | 73 | 64 | 74 | 51 | 47 |
| Not frequent or infrequent | 69 | 68 | 43 | 68 | 86 | 59 | 52 | 60 | 48 | 35 |
| Frequently | 80 | 93 | 118 | 94 | 84 | 24 | 13 | 19 | 36 | 9 |
| Very frequently | 22 | 29 | 64 | 45 | 26 | 11 | 7 | 11 | 12 | 7 |

*Table 16*

Mean, Standard Deviation, and Frequency of Importance of Sources for Agricultural Production, Practices, and Management

| | Extension / University | Extension Publication | Other Farmers | Vendors | Production Magazines | TV | Radio | Newspapers | Internet | Email |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 3.77 | 3.71 | 4.05 | 3.60 | 3.33 | 2.36 | 2.17 | 2.33 | 2.47 | 2.0 |
| Standard Deviation | 1.140 | 1.126 | .898 | 1.057 | 1.130 | 1.217 | 1.181 | 1.217 | 1.350 | 1.214 |
| Rating | Frequency of Response | | | | | | | | | |
| Not at all Important | 17 | 17 | 5 | 13 | 25 | 83 | 99 | 86 | 93 | 129 |
| Not Important | 23 | 23 | 10 | 22 | 29 | 62 | 57 | 60 | 35 | 41 |
| Neither | 33 | 40 | 37 | 73 | 66 | 61 | 60 | 64 | 54 | 55 |
| Important | 115 | 116 | 120 | 99 | 104 | 38 | 25 | 33 | 54 | 17 |
| Very Important | 70 | 63 | 84 | 52 | 29 | 13 | 11 | 14 | 17 | 14 |

## Confirmatory Factor Analysis

Following data collection and examining the descriptive statistics, confirmatory factor analyses and structural equation modeling were conducted by using SPSS and AMOS. Separate confirmatory factor analysis for each of the constructs (stage of change, decisional balance, perceived compatibility, perceived ease of use, and precision agriculture self-efficacy) was conducted. Convergent validity was confirmed by examining the factor loadings on the respective latent variables and determining if the factor loading was greater than .5 and was significant ( $p < .05$) (Anderson & Gerbing, 1988; Bollen, 1989). Convergent validity of each construct is described in this section.

Cronbach alpha estimates were utilized to test internal consistency of the stage of change subscales and perceived ease of use, perceived compatibility and precision agriculture self-efficacy scales. Discriminant validity was determined by comparing the chi-square ($\chi^2$) difference between a constrained model and a model where the constructs were allowed to freely covary for each pair of factors (Anderson & Gerbing, 1988).

Several fit indices were evaluated to determine the adequacy of each of these constructs to fit the data. $\chi^2$ statistic, $\chi^2$ to degrees of freedom ratio, Root Mean Square Residual (RMSEA), Comparative Fit Index (CFI), Normed Fit Index (NFI), and Tucker Lewis Index (TLI), were used to evaluate how well the constructs fits the data.

## Stage of Change

Confirmatory factor analysis was performed on the stage of change construct. The six factors in the stage of change construct are maintenance, action, preparation, contemplation, precontemplation-believing, and precontemplation non-believing. The initial confirmatory factor analysis indicated that three items had standardized regression weights of less then .5. Items 64 (precontemplation-believing) had a regression weight of .25. Item 63 (precontemplation-believing) had a standardized regression weight of .432 and Item 61 (precontemplation-nonbelieving) had a standardized regression weight of .474. Although these three items were significant, the standardized regression weights were less than the level needed to indicate convergent validity (Anderson & Gerbing, 1988; Bollen, 1989). All three of these items were dropped from the analysis. The mean, standard deviations, standardized regression weights, and critical ratio for each item of these stage of change factors are presented in Table 17.

For the maintenance factor, the reliability coefficient was .906, indicating excellent reliability (Cicchetti, 1994). The standardized regression weights for the maintenance factor were above .7 and were significant ($p < .001$). For the action factor, reliability coefficient was .884, indicating excellent reliability (Cicchetti, 1994). The standardized regression weights for the action factor were above .6 and were significant ($p < .001$).

*Table 17*

Mean Standard Deviation, Standardized Regression Weights, and Internal Consistency Estimates for Stage of Change Construct

| Subscales and Indicators | Mean | Standard Deviation | Standardized Regression Weight | Critical Ratio |
|---|---|---|---|---|
| Maintenance .906* | | | | |
| Maintenance 54 | 2.02 | 1.030 | .743 | 15.398 |
| Maintenance 57 | 2.11 | 1.065 | .777 | 16.675 |
| Maintenance 68 | 2.00 | 1.043 | .938 | 25.566 |
| Maintenance 71 | 1.89 | 1.000 | .906 | -- |
| Action .884* | | | | |
| Action 56 | 2.12 | 1.112 | .689 | 13.120 |
| Action 60 | 2.04 | 1.061 | .864 | 19.188 |
| Action 62 | 2.14 | 1.125 | .820 | 17.373 |
| Action 65 | 2.18 | 1.137 | .874 | -- |
| Preparation .897* | | | | |
| Preparation 67 | 2.18 | 1.060 | .901 | 17.361 |
| Preparation 70 | 1.97 | 0.974 | .865 | 16.386 |
| Preparation 73 | 1.97 | .976 | .733 | 13.070 |
| Preparation 76 | 2.18 | 1.067 | .803 | -- |

* Cronbach Alpha Statistic
Note: All factor loadings are significant ($p < .001$).

Table 17 Continued

| Subscales and Indicators | Mean | Standard Deviation | Loadings | Critical Ratio |
|---|---|---|---|---|
| Contemplation .849* | | | | |
| Contemplation 59 | 2.69 | 1.205 | .711 | 12.274 |
| Contemplation 66 | 2.57 | 1.156 | .671 | 11.424 |
| Contemplation 69 | 2.54 | 1.182 | .876 | 16.008 |
| Contemplation 75 | 2.56 | 1.182 | .805 | -- |
| PreContemplation Believing .712* | | | | |
| PreContemplation Believing 72 | 2.78 | 1.100 | .730 | 7.030 |
| PreContemplation Believing 74 | 3.00 | 1.175 | .713 | 7.055 |
| PreContemplation Believing 77 | 3.14 | 1.152 | .559 | -- |
| PreContemplation Non Believing .704* | | | | |
| PreContemplation Non Believing 53 | 3.10 | 1.176 | .780 | |
| PreContemplation Non Believing 55 | 2.98 | 1.263 | .693 | 9.112 |
| PreContemplation Non Believing 58 | 3.16 | 1.251 | .611 | 7.587 |

* Cronbach Alpha Statistic
Note: All factor loadings are significant ($p < .001$).

The standardized regression weights for the preparation factor were above .7 and were significant ($p < .001$). The Cronbach alpha estimates for the preparation factor was .897, indicating excellent reliability (Cicchetti, 1994). The standardized regression weights for contemplation were above .6 and were significant ($p < .001$).

The Cronbach alpha estimates for the preparation factor was .849, indicating excellent reliability (Cicchetti, 1994).

Two items of the precontemplation believing subscale (items 63 and 64) had regression weights of less than .5 and were dropped from the model. The three remaining items for this subscale had regression weights greater than .5 and were significant ($p < 001$), indicating convergent validity (Anderson & Gerbing, 1988; Bollen, 1989). The Cronbach alpha statistic for the 3 item precontemplation-believing subscale was .712. While the goal for internal consistency is at least .8 (Nunnally, 1978), an internal consistency of .7 is considered to be adequate (Cicchetti, 1994).

Item number 61 in the precontemplation-non believing subscale was dropped because its standardized regression weight was less than .5 (Anderson & Gerbing, 1988; Bollen, 1989). The three remaining items of the precontemplation non-believing subscale had standardized regression weights of more than .6. The Cronbach alpha statistic for the precontemplation-non believing subscale was .704, indicating adequate reliability (Cicchetti, 1994). The mean, standard deviations, standardized regression weights, and critical ratio for each of these items are presented in Table 17.

Discriminant validity was determined by comparing the $\chi^2$ difference between a constrained model and a model where the factors were allowed to freely covary for each pair of factors in the model (Anderson & Gerbing, 1988). The test consists of calculating the $\chi^2$ difference between a model which constrains the correlations between two factors to unity and another model which allows the correlations between the constructs to covary. This test was performed for the stage of change factors. The comparison for the constrained and unconstrained model was significant. The $\chi^2_{diff}$ ($df_{diff}$ =15, N =261) = 77.433 ($p < .001$), thereby providing evidence of discriminant validity and confirming the six-factor structure for the stage of change construct.

The goodness of fit for the stage of change construct was examined by using the $\chi^2$ statistic, $\chi^2$ to degrees of freedom ratio, RMSEA, CFI, NFI, and TLI. The $\chi^2$ statistic was significant ($\chi^2$= 538.582, df = 194, $p < 0.001$) for the hypothesized model which indicated poor fit. The ratio $\chi^2$ to degrees of freedom ratio was 2.78 was under the recommended benchmark of 3 (Kettinger et al., 1995; Segars & Grover, 1993) which also indicated an adequate fit. Additionally, the RMSEA statistic (.083) indicated an adequate fit. The CFI (.914) indicated that the stage of change CFA model was an adequate fit. NFI (.873) and TLI (.898) were slightly below .90. The goodness of fit measures are provided in Table 18. Additionally, the overall model for the stage of change construct is shown in Figure 3.

*Table 18*

Goodness of Fit Measures for the Stage of Change Construct

| Fit Index | Recommended Values | Model |
|---|---|---|
| $\chi^2$ | p > .05 | $\chi^2$ = 538.582;<br>df = 194; p < 0.001 |
| $\chi^2$ / df | < 3 | 2.776 |
| RMSEA | < .05 (close fit)<br><.08 (good fit)<br><.10 (adequate fit) | .083 |
| CFI | > .90 (adequate fit)<br>> .95 (good fit) | .914 |
| NFI | > .90 (adequate fit)<br>> .95 (good fit) | .873 |
| TLI | > .90 (adequate fit)<br>> .95 (good fit) | .898 |

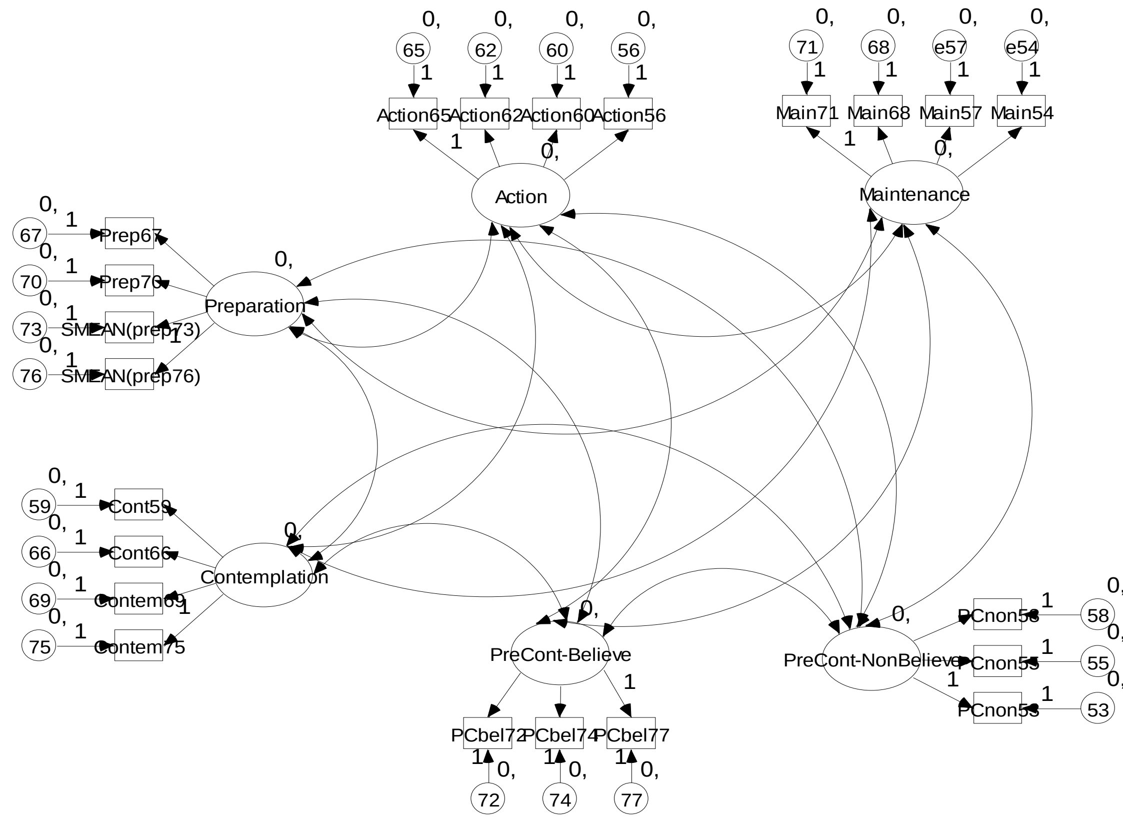


Figure 3. Confirmatory factor analysis model for the stage of change construct

Staging Algorithm

A stage score is calculated using the standardized (mean) scores for each of six factors—maintenance, action, preparation, contemplation, precontemplation-believing, and precontemplation-nonbelieving were computed. The standardized scores for maintenance, action, preparation, and contemplation scales were summed, and then, the standardized scores for precontemplation subscales were subtracted to create a stage score. The following formula demonstrates the calculation for this score:

Stage Score =

+ mean(action) + mean(maintenance) + mean(contemplation)

- mean(precontemplation-believing) - mean(precontemplation-nonbelieving)

## Decisional Balance

Confirmatory factor analysis was performed on the pros and cons subscales of the decisional balance. For pros subscale, the reliability coefficient is .982, thus, indicating excellent internal consistency (Cicchetti, 1994). The Cronbach alpha reliability statistic was .964 for the cons subscale, indicating excellent internal consistency.

Confirmatory factor analysis was conducted on decisional balance factor. The original CFA model for decisional balance construct is shown in Figure 4. This model indicated that the error variances of the indicator variables were assumed to be uncorrelated. For the decisional balance CFA model, the $\chi^2$ statistic was significant ($\chi^2$ = 1998.24, df= 349, p < .001), indicating a poor fit. The $\chi^2$ to degrees of freedom ratio was 5.73 above the recommended 3 (Kettinger et al., 1995; Segars & Grover,

1993) and 5 (Wheaton et al., 1977). Additionally, the RMSEA statistic (.131) indicated an inadequate fit. Other measures showed that the decisional balance construct was a good fit where the indices CFI, TLI, and NFI were all above .90. These goodness of fit measures are shown in Table 19.

Several items appeared to share error variance because the correlations between many of them appeared to be greater than the correlations with the other items in the construct. This seems reasonable after evaluating the content of the items. From the pros factor, items (78, 79, and 80) concerning reducing costs, increasing yields and increasing profits appeared to share the error variances. Additionally, the error terms for items (81 and 82) concerning reducing chemicals and targeting nutrients also appeared to be correlated. The two items (84 and 89) both address the benefit of obtaining detail information from the fields. Two items (90 and 91) relate to reducing farm labor and managing labor farm labor. Also, items, 78 and 90, relate to reducing costs and reducing labor. Since reducing labor obviously will reduce cost, these two items also shared the error variance associated with these two items.

Of the cons indicator variables, several appeared to share error variances. Items 93 and 105 both relate to the expensive of the precision agriculture tools. Item 93 states, “Precision agriculture tools are expensive”, and item 105 states, “Precision agriculture tools are expensive to keep up-to-date.” Items 94 and 95 relate to skills and training needed to be able to use precision agriculture tools.” Additionally, item 96 relates to data that are difficult to interpret and item 94 relates to skills that the participant does not have. Items 102 and 103 relate to the precision agriculture tools are difficult to use. Specifically, item 102 relates to the difficulty of integrating precision agriculture into traditional farming. Also, 104 is an item indicating the difficulty of keeping abreast of new precision agriculture technologies. Item 101 relates to the time consideration of precision agriculture and item 102 relates to that the difficulty of integrating precision agriculture into traditional farming.

Figure 5 shows the modified CFA model of the decisional balance construct. The $\chi^2$ statistic was significant ($\chi^2$ = 1128.50, df = 333, p < .001) for the modified CFA model of the decisional balance construct indicating a poor fit. However, a significant $\chi^2$ is not uncommon because $\chi^2$ is very sensitive to sample size (Browne & Mels, 1992). Although the $\chi^2$ was significant, the $\chi^2$ to degrees of freedom ratio (3.39) was under the recommended benchmark of 5 (Wheaton et al., 1977), but over the recommended benchmark of 3 (Kettinger et al., 1995; Segars & Grover, 1993). The RMSEA statistic (.096) also indicated an acceptable fit. CFI and TLI were over .90, indicating an adequate fit. However, the NFI estimate was slightly under the .90 benchmark. These goodness of fit measures for the original CFA model and the modified CFA model of the decisional balance are shown in Table 19.

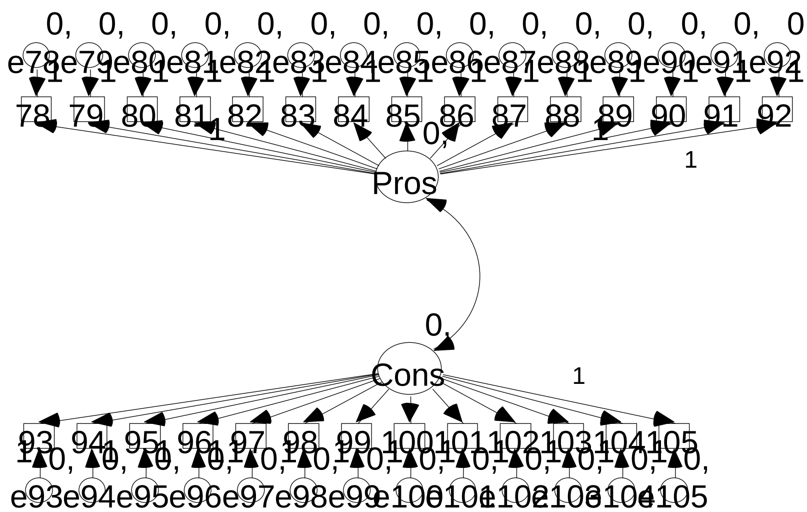


Figure 4. Confirmatory factor analysis for decisional balance

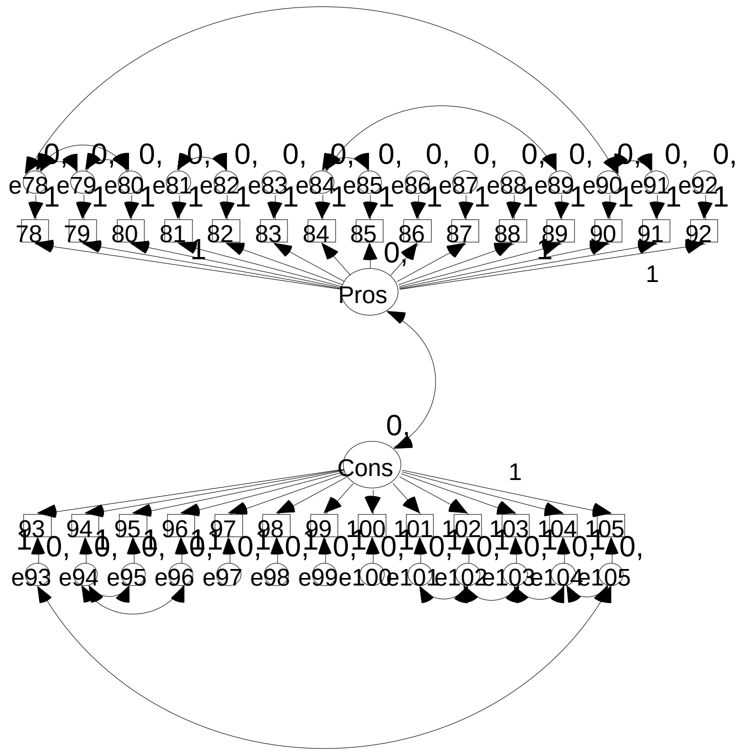


Figure 5. Modified confirmatory factor analysis model for decisional balance

Discriminant validity was determined by comparing the $\chi^2$ difference between a constrained model and a model where the factors were allowed to freely covary for each pair of factors in the model (Anderson & Gerbing, 1988). The comparison for the constrained and unconstrained model was significant. The $\chi^2_{diff}$ ($df_{diff}$ =26, N =261) = 61.953 ($p < .001$) provided evidence of discriminant validity and confirmed decisional balance as a two-factor construct.

*Table 19*

Goodness of Fit Measures for the Decisional Balance Construct

| Fit Index | Recommended Values | Model | Modified CFA Model |
|---|---|---|---|
| $\chi^2$ | p > .05 | $\chi^2$ = 1715.839<br>df = 298; p < .001 | $\chi^2$ = 1128.500<br>df= 333; p < .001 |
| $\chi^2$ / df | < 3 | 5.758 | 3.389 |
| RMSEA | < .05 (close fit)<br>< .08 (good fit)<br><. 10 (adequate fit) | .131 | .096 |
| CFI | > .90 (adequate fit)<br>> .95 (good fit) | .848 | .922 |
| NFI | > .90 (adequate fit)<br>> .95 (good fit) | .822 | .893 |
| TLI | > .90 (adequate fit)<br>> .95 (good fit) | .834 | .911 |

The standardized regression weights for the pros scale were above .75 and significant ($p < .001$), confirming convergent validity. The loadings for the cons subscale were above .74 and were significant ($p <.001$), confirming convergent validity. The Cronbach alphas of these two scales were very high which is expected because the large number of items within each scale (Hinkin, 1995). The pros subscale had 15 items and the cons subscale had 13 items. The mean, standard deviations, standardized regression weights, and critical ratio for each of these items are presented in Table 20.

*Table 20*

Mean, Standard Deviation, Standardized Regression Weights and Critical Ratio for Pros and Cons Subscales of Decisional Balance Construct

| Subscales and Indicators | | Mean | Standard Deviation | Standardized Regression Weight | Critical Ratio |
|---|---|---|---|---|---|
| Pros | .982* | | | | |
| Reduce Costs 78 | | 3.44 | 1.407 | .912 | 17.542 |
| Increase Yields 79 | | 3.55 | 1.391 | .919 | 17.711 |
| Increase Profits 80 | | 3.61 | 1.410 | .925 | 17.860 |
| Reduce Chemicals 81 | | 3.58 | 1.376 | .936 | 18.219 |
| Target Nutrients 82 | | 3.49 | 1.358 | .920 | 17.750 |
| Environmental Information 83 | | 3.31 | 1.359 | .872 | 16.535 |
| Analyze Field Data 84 | | 3.34 | 1.380 | .901 | 17.350 |
| Increase Land Value 85 | | 3.25 | 1.419 | .855 | 16.049 |
| Increase Cropland 86 | | 3.10 | 1.385 | .813 | 15.042 |
| Increase Management Information 87 | | 3.36 | 1.371 | .865 | 16.312 |
| Decrease Financial Risks 88 | | 3.43 | 1.396 | .857 | 16.099 |
| Collect Information on Variability 89 | | 3.41 | 1.336 | .914 | 17.710 |
| Reduce Farm Labor 90 | | 3.35 | 1.389 | .877 | 16.671 |
| Manage Labor 91 | | 3.19 | 1.350 | .874 | 16.620 |
| Create Experiments 92 | | 3.16 | 1.333 | .788 | -- |

*Cronbach Alpha Statistic
Note: All factor loadings are significant ($p < .001$).

Table 20 Continued

| Subscales and Indicators | Mean | Standard Deviation | Standardized Regression Weight | Critical Ratio |
|---|---|---|---|---|
| Cons .964* | | | | |
| Expensive 93 | 3.67 | 1.297 | .743 | 13.289 |
| Require Skills 94 | 3.10 | 1.285 | .834 | 12.848 |
| Require Training 95 | 3.17 | 1.274 | .838 | 12.938 |
| Data Difficult to Training 96 | 2.97 | 1.299 | .852 | 13.135 |
| Dependent on Machinery 97 | 3.28 | 1.272 | .831 | 12.874 |
| Cost Effective 98 | 3.39 | 1.327 | .809 | 12.574 |
| Require Support Services 99 | 3.22 | 1.345 | .893 | 13.739 |
| Understanding of Agronomy 100 | 3.08 | 1.334 | .838 | 12.924 |
| Time Consuming 101 | 3.13 | 1.277 | .814 | 12.628 |
| Difficult to Integrate into Traditional Farming 102 | 3.08 | 1.281 | .821 | 12.802 |
| Difficult to Use 103 | 2.98 | 1.246 | .826 | 12.861 |
| Difficult to Abreast Technology 104 | 3.13 | 1.323 | .846 | 15.974 |
| Expensive to Keep Up-to-Date 105 | 3.39 | 1.450 | .699 | -- |

*Cronbach Alpha Statistic
Note: All factor loadings are significant ($p < .001$).

The decisional balance variable was calculated by subtracting the standardized (mean) scores of the cons from the standardized (mean) scores of the pros. Thus, the decisional balance score is the standardized difference between the pros and cons. For example, a very high pro score and a very low con score would yield a very high decisional balance score. It is possible for an individual to score high on both pros and cons. One elementary question is whether there is a statistical difference in the pros and cons. A paired t-test showed that there is a significant difference ($t = 3.552$, $df = 260$, $p < .001$) between the two factors. Additionally, the pros and cons were correlated ($r = .781$, $p < .001$).

## Stages and Decisional Balance Correlations

It is hypothesized that the decisional balance influences stage of change. When discrete categories for each stage are used in the behavioral studies, the pros increase and cons decrease with each progression in stage. In this study, a continuous measure was used; therefore, it was hypothesized, in H1b, that there is a positive correlation between the pros and stage of change, and in H1c, that there is a negative correlation between the cons and stage of change. The results indicated that there was a significant positive correlation between pros and stage ($r = .481$, $p < .001$) and a positive correlation between the cons and stage ($r = .196$, $p = .001$). H1a was supported, but Hypothesis 1b was not. While a positive correlation between the cons and stage, instead of a negative correlation, may be surprising, some studies have found a similar result (Levesque et al., 2001; Velicer, DiClemente, Prochaksa, & Brandenburg, 1985). Behavioral researchers explain that as individuals move through the middle stages and into the action stages, they begin to recognize the change (or the technology) is more difficult than they had originally thought when they were in the beginning stages (Velicer et al., 1985).

As expected, there was also a positive correlation between the decisional balance and stage ($r = .410$, $p < .001$). The correlations between the pros, cons, decisional balance and stage are presented in Table 21.

*Table 21*

Means, Standard Deviation, and Correlations between Pros, Cons, Decisional Balance and Stage of Change

| | Pros | Cons | Decisional Balance | Stage |
|---|---|---|---|---|
| Mean | 3.37 | 3.20 | .17 | 2.72 |
| Standard Deviation | 1.231 | 1.096 | .780 | 4.017 |
| **Variable** | **Correlations** | | | |
| Pros | 1 | | | |
| Cons | .781*** | 1 | | |
| Decisional Balance | .481*** | -.171** | 1 | |
| Stage | .434*** | .196** | .410*** | 1 |

*p-level < .05; **p-level <. 01; ***p-level < .001

Precision Agriculture Self-Efficacy

Confirmatory factor analysis was conducted on precision agriculture self-efficacy factor. The original CFA model for precision agriculture self-efficacy construct is shown in Figure 6. This model indicated that the error variances of the indicator variables were assumed to be uncorrelated. The $\chi^2$ to degrees of freedom ratio was greater than 10 which is well above the recommended 3 (Kettinger et al., 1995; Segars & Grover, 1993) and 5 (Wheaton et al., 1977). RMSEA statistic also indicated an inadequate fit (.191). Because the correlations between items 38 and 39 appeared to be greater than the correlations with the other items in the construct, their error terms were allowed to correlate. Actually, Hill et al (1987) also allowed the error terms of these two variables to correlate. It seems reasonable that items, 38 and 39, could share error variance because both items relate to the understanding of precision agriculture. Item 38 states "I will never understand how to precision agriculture tools" and item 39 states "Only a few experts really understand how precision agriculture tools work."

The modified CFA model for precision agriculture self-efficacy, showing that the error terms for items, 38 and 39, were correlated is shown in Figure 7. For the modified CFA precision agriculture self-efficacy, the $\chi^2$ statistic was not significant ($\chi^2 = .134$, df = 1, p = .134), indicating a good fit. Additionally, the $\chi^2$ to degrees of freedom ratio was .134, meeting the recommended level of 3 (Kettinger et al., 1995; Segars & Grover, 1993), indicating a close fit. The RMSEA statistic (.000) also indicated a close fit. Other measures indicated that the model for the precision agriculture self-efficacy was a good fit. These goodness of fit measures for the original CFA model and the modified CFA model for the precision agriculture self-efficacy construct are shown in Table 22.

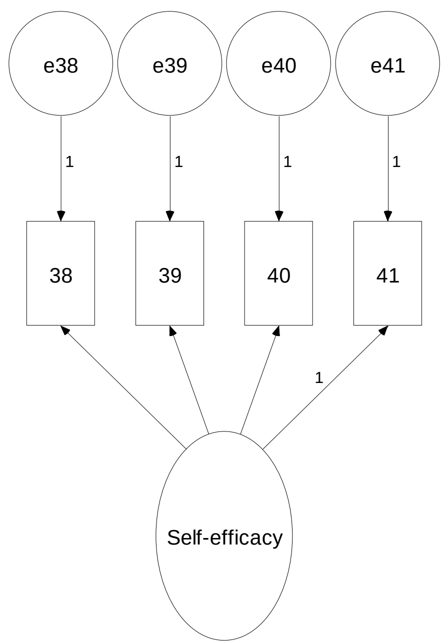


Figure 6. Confirmatory factor analysis model for precision agriculture self-efficacy

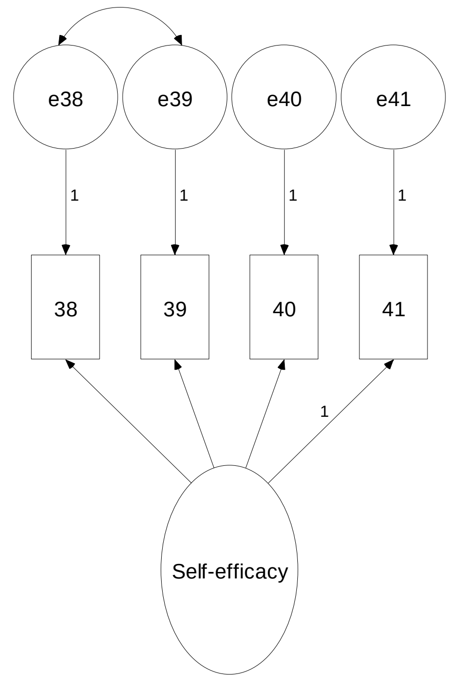


Figure 7. Modified confirmatory factor analysis model for precision agriculture self-efficacy

*Table 22*

Goodness of Fit Measures for the Precision Agriculture Self-Efficacy Construct

| Fit Index | Recommended Values | Model | Modified Model |
|---|---|---|---|
| $\chi^2$ | $p > .05$ | $\chi^2 = 20.756$; $df = 2$; $p < 0.001$ | $\chi^2 = .134$; $df = 1$; $p = .714$ |
| $\chi^2 / df$ | $< 3$ | 10.378 | .134 |
| RMSEA | < .05 (close fit)<br>< .08 (good fit)<br>< .10 (adequate fit) | .191 | .000 |
| CFI | > .90 (adequate fit)<br>> .95 (good fit) | .944 | 1.000 |
| NFI | > .90 (adequate fit)<br>> .95 (good fit) | .939 | 1.000 |
| TLI | > .90 (adequate fit)<br>> .95 (good fit) | .832 | 1.015 |

The standardized weights for each item were above .60 and were all significant at the .001 level, indicating convergent validity. The Cronbach alpha, indicating internal consistency, for precision agriculture self-efficacy factor (.804) was above the recommended level (Cicchetti, 1994; Nunnally, 1978). The mean, standard deviation, standardized regression weights, and the critical ratio of each item for the precision agriculture self-efficacy factor are shown in Table 23.

*Table 23*

Means, Standard Deviation, Standardized Regression Weights and Critical Ratio for the Precision Agriculture Self-Efficacy Construct

| Item | Mean | Standard Deviation | Standardized Regression Weight | Critical Ratio |
|---|---|---|---|---|
| Self-efficacy 38 | 3.77 | 1.011 | .513 | 7.155 |
| Self-efficacy 39 | 3.48 | 1.115 | .684 | 9.337 |
| Self-efficacy 40 | 3.50 | .969 | .860 | 9.463 |
| Self-efficacy 41 | 3.27 | .913 | .695 | -- |

Notes: Cronbach Alpha Statistic = .802.
All factor loadings are significant ($p < .001$).

Perceived Compatibility with Existing Operations and Practices

Confirmatory factor analysis was conducted on perceived compatibility with existing operations and practices. The original CFA model for the perceived compatibility construct, developed from the Moore and Benbsat (1991) study, is shown in Figure 8 and assumes that none of the error terms are correlated. The $\chi^2$ was significant ($\chi^2 = 46.24$, df = 2, $p < .001$) for the original CFA model for perceived compatibility, indicating poor fit. Additionally, the $\chi^2$ to degrees of freedom ratio for the original CFA model was 23.12, well above the recommended level of 3 (Kettinger et al., 1995; Segars & Grover, 1993) and 5 (Wheaton et al., 1977). The RMSEA statistic also indicated an inadequate fit (.185).

Because the correlations between items 42 and 43 appeared to be greater than the correlations with the other items in the construct, their error variances were allowed to correlate. Item 42 states "Precision agriculture is compatible with all aspects of my farm operation," and item 43 states "Precision agriculture is completely compatible with my current farming situation." It seems reasonable that these items could share in the error variance because both items relate to the farming operation and situation.

In the modified CFA model for the perceived compatibility, the two error terms associated with these two items were allowed to be correlated. Figure 9 shows the modified model. The $\chi^2$ statistic was not significant ($\chi^2$ = .280, df = 1, p = .596) for the modified model which indicated good fit. The ratio $\chi^2$ to degrees of freedom ratio for the modified CFA model was .280, meeting the recommended level of 3 (Kettinger et al., 1995; Segars & Grover, 1993). Other measures indicated that the modified model for the perceived compatibility was a good fit, as well. These goodness of fit measures for the original CFA model and the modified CFA model for the perceived compatibility construct are shown in Table 24.

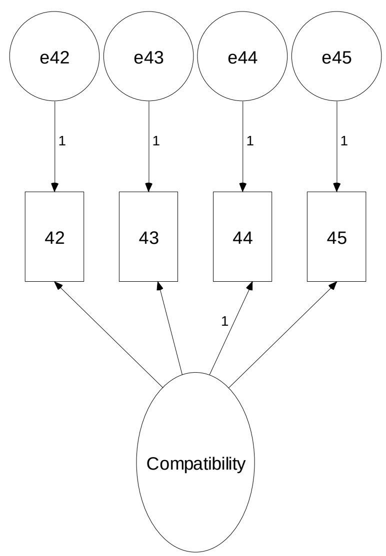


Figure 8. Confirmatory factor analysis model for perceived compatibility

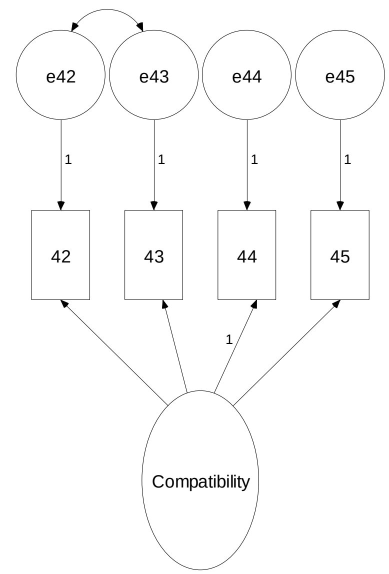


Figure 9. Modified confirmatory factor analysis model for perceived compatibility

*Table 24*

Goodness of Fit Measures for the Perceived Compatibility with Existing Operations and Practices Construct

| Fit Index | Recommended Values | Model | Modified Model |
|---|---|---|---|
| $\chi^2$ | p > .05 | $\chi^2$ = 46.24; df = 2; p < .001 | $\chi^2$ = .280; df = 1; p = .596 |
| $\chi^2$ / df | < 3 | 23.12 | .280 |
| RMSEA | < .05 (close fit) | .292 | .000 |
| | < .08 (good fit) | | |
| | < .10 (adequate fit) | | |
| CFI | > .90 (adequate fit) | .945 | 1.000 |
| | > .95 (good fit) | | |
| NFI | > .90 (adequate fit) | .943 | 1.000 |
| | > .95 (good fit) | | |
| TLI | > .90 (adequate fit) | .836 | 1.005 |
| | > .95 (good fit) | | |

The standardized weights for each item were well above .65 and were all significant at the .001 level, indicating convergent validity (Anderson & Gerbing, 1988). The Cronbach alpha, indicating internal consistency, for perceived compatibility (.907) was well all above the recommended level. The mean, standard deviation, standardized regression weights, and critical ratio of each item for the perceived compatibility factor are shown in Table 25.

*Table 25*

Means, Standard Deviation, Factor Loadings, and Critical Ratio for Perceived Compatibility with Existing Operations and Practices Construct

| Item | Mean | Standard Deviation | Standardized Regression Weight | Critical Ratio |
|---|---|---|---|---|
| Compatibility 42 | 2.61 | .987 | .676 | 13.506 |
| Compatibility 43 | 2.59 | .954 | .972 | 25.805 |
| Compatibility 44 | 2.63 | 1.020 | .717 | 14.894 |
| Compatibility 45 | 2.56 | .997 | .926 | -- |

Notes: Cronbach Alpha Statistic = .907.
All factor loading is significant ($p < .001$).

## Perceived Ease of Use

Confirmatory factor analysis was conducted on perceived ease of use factor. The original CFA model for the perceived ease of use construct is shown in Figure 9. The $\chi^2$ of the original CFA model for perceived of use was significant ($\chi^2$ = 117.55, df = 14, p <.001). Also, the $\chi^2$ to degrees of freedom ratio was 8.40, well above the recommended 3 (Kettinger et al., 1995; Segars & Grover, 1993) and 5 (Wheaton et al., 1977). The RMSEA statistic also indicates an inadequate fit (.169). In the original CFA model, as developed by Davis (1989), the error variances were assumed to be uncorrelated. The CFA model for the perceived ease of use factor is shown in Figure 10.

Because the correlations between items 47 and 48 appeared to be greater than the correlations with the other items in the construct, their error terms were allowed to correlate. Item 47 states "I find it is easy to get precision agriculture tools to do what I want it to do," and item 48 states "It is easy for me to remember how to perform tasks using precision agriculture tools." It seems reasonable that these items could share error variance because both items relate to performing tasks with precision agriculture technologies. The $\chi^2$ for the CFA model for the seven item model allowing items 47 and 48 to correlated was 57.112 (df = 13, p < .001). The $\chi^2$ and other goodness of fit measures for this CFA model with the seven items are shown in Table 24.

Additionally, item 52, "I find precision agriculture tools easy to use," captures concept of all of the other six items. Dropping this item improved the fit of the CFA model. After item 52 was dropped from the model, the $\chi^2$ changed to 12.075 (df = 8, p = .148). Dropping this item substantially improved the fit of the CFA and did not substantially change the internal consistency. Cronbach alpha changed from .939 with the seven item scale to .924 with the six item scale.

The CFA model for perceived ease of use was modified so that the error terms items 47 and 48 were allowed to be correlated, and item 52 was dropped from the model. Figure 11 shows the modified CFA model for the perceived ease of use factor.

The goodness of fit measures for the modified model are shown in Table 24. The $\chi^2$ statistic for the modified CFA model of the perceived ease of use factor was not significant ($\chi^2$ = 12.075, df = 8, p = .148), indicating a close fit. The ratio $\chi^2$ to degrees of freedom ratio for the modified CFA model was 1.51, meeting the recommended level of 3 (Kettinger et al., 1995; Segars & Grover, 1993). Additionally, the RMSEA statistic and the other goodness of fit indices indicted a good fit for the modified CFA model.

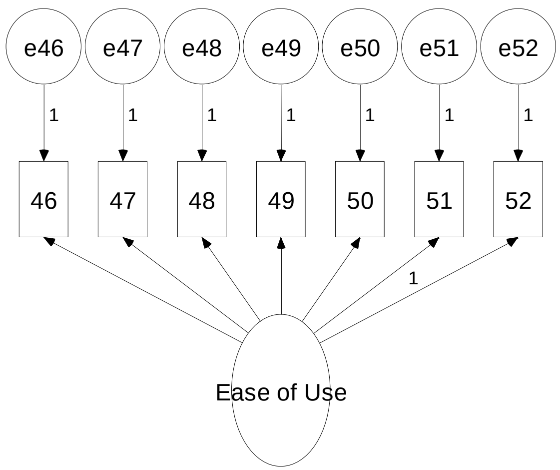


Figure 10. Confirmatory factor analysis model for perceived ease of use

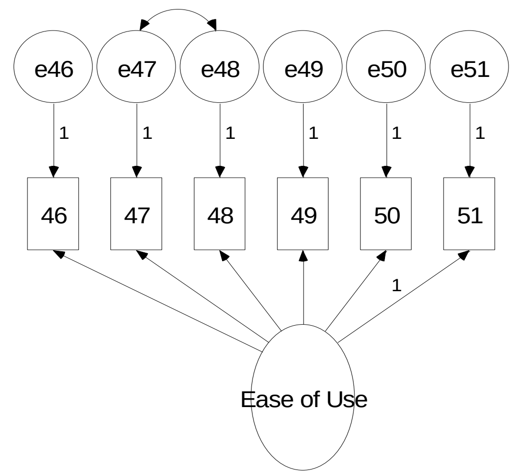


Figure 11. Modified confirmatory factor analysis model for perceived ease of use

*Table 26*

Goodness of Fit Measures for the Perceived Compatibility with Existing Operations and Practices Construct

| Fit Index | Recommended Values | Original CFA Model | Modified CFA Model with 7 Indicators | Modified CFA Model with 6 Indicators |
|---|---|---|---|---|
| $\chi^2$ | p > .05 | $\chi^2$ = 117.547; df = 14; p < .001 | $\chi^2$ = 57.112 df = 13, p < .001 | $\chi^2$ =12.075; df = 8; p = .148 |
| $\chi^2$ / df | < 3 | 8.396 | 4.393 | 1.509 |
| RMSEA | < .05 (close fit) | .169 | .114 | .000 |
| | < .08 (good fit) | | | |
| | < .10 (adequate fit) | | | |
| CFI | > .90 (adequate fit) | .933 | .971 | .933 |
| | > .95 (good fit) | | | |
| NFI | > .90 (adequate fit) | .925 | .963 | .981 |
| | > .95 (good fit) | | | |
| TLI | > .90 (adequate fit) | .899 | .954 | .925 |
| | > .95 (good fit) | | | |

The standardized weights for each item were well above .70 and were all significant at the .001 level, indicating convergent validity. The Cronbach alpha, indicating internal consistency, for perceived ease of use (.924) was well all above the recommended level. The mean, standard deviation, standardized regression weights and critical ratio for each item for the perceived ease of use factor are shown in Table 27.

*Table 27*

Means, Standard Deviation, Factor Loadings, and Critical Ratio for Perceived Ease of Use Construct

| Items | Mean | Standard Deviation | Standardized Regression Weights | Critical Ratio |
|---|---|---|---|---|
| Ease of Use 46 | 2.91 | .932 | .808 | 15.579 |
| Ease of Use 47 | 2.69 | .855 | .716 | 13.067 |
| Ease of Use 48 | 2.76 | .911 | .734 | 13.531 |
| Ease of Use 49 | 2.78 | .924 | .864 | 17.291 |
| Ease of Use 50 | 2.79 | .840 | .894 | 18.237 |
| Ease of Use 51 | 2.90 | .943 | .837 | -- |

Notes: Cronbach Alpha Statistic = .924.
All factor loadings are significant ($p < .001$).

## Path Analysis Using Structural Equation Modeling

The hypothesized research model was evaluated using AMOS which simultaneously estimates the model, including latent and observed variables, exogenous and endogenous variables, and the paths to these variables. The overall fit of the model was examined. The relative strength and significance of the individual paths was also evaluated.

This model describes the mediating effects of precision agriculture self-efficacy, perceived ease of use, compatibility, communication behaviors, and decisional balance on precision agriculture stage of change. Several goodness of fit measures were used to analyze the structural model to verify its ability to fit the data. These measures were $\chi^2$ statistic, $\chi^2$ to degrees of freedom ratio, RMSEA, CFI, NFI, and TLI. After the model was examined for fitting the data adequately, the model and the hypotheses were tested by analyzing the significance of the paths. Additionally, the standardized weights, as a relative strength of the paths, and the explanatory power were examined.

### Goodness of Fit

The hypothesized model with the indicator variables shown is given in Figure 12. The goodness of fit measures are shown in Table 28. The $\chi^2$ statistic was significant ($\chi^2$ = 315.136; df = 160; $p < .001$) for the hypothesized model which indicated a poor fit. However, a significant $\chi^2$ is not uncommon because $\chi^2$ is very sensitive to sample size (Browne & Mels, 1992). Although the $\chi^2$ was significant, the

$\chi^2$ to degrees of freedom ratio was 1.97, under the recommended benchmark of 3 (Kettinger et al., 1995; Segars & Grover, 1993) , indicating an adequate fit.

Another measure of a good fit is the RMSEA. A value of zero indicates a perfect fit, .05 or less indicates a close fit, less than of .08 indicates an adequate fit, and .10 or greater is not acceptable (Browne & Cudeck, 1993). The RMSEA statistic of the model was .061, indicating an adequate fit.

Three goodness of fit indices were also used. These indices range from zero to one, with values exceeding .90 indicating an adequate fit and values exceeding .95 indicating a good fit (Hu & Bentler, 1999). CFI and TLI resulted in values greater than .94, thus indicating an adequate fit. NFI was close to the .90 benchmark with a value of .894. These goodness of fit measures, shown in Table 28, provided support for the hypothesized model.

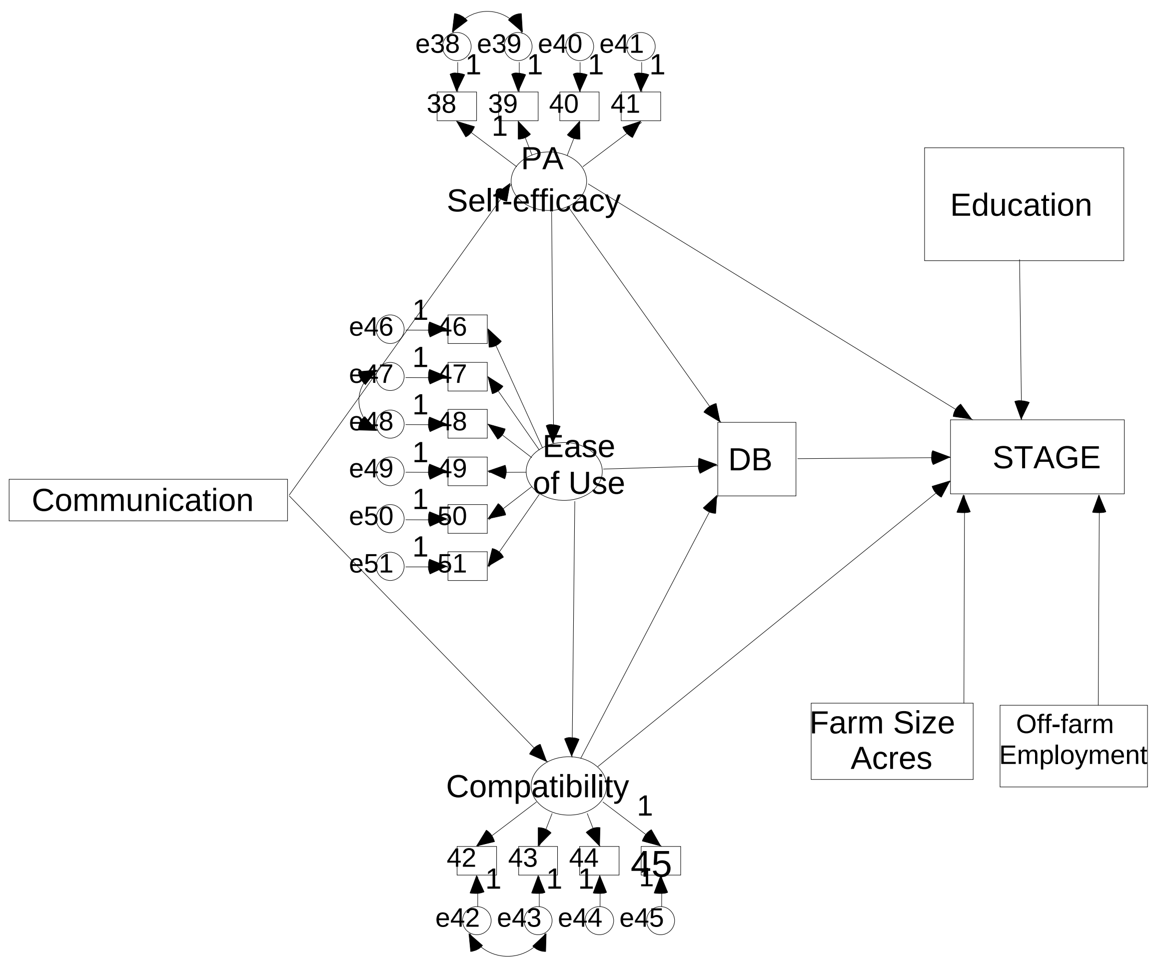


Figure 12. Hypothesized model with indicator variables

*Table 28*

Goodness of Fit Measures

| Fit Index | Recommended Values | Model |
| --- | --- | --- |
| $\chi^2$ | p > .05 | $\chi^2$ = 315.136; |
| | | df = 160; p <.001 |
| $\chi^2$ / df | < 3 | 1.97 |
| RMSEA | < .05 (close fit) | .061 |
| | < .08 (good fit) | |
| | < .10 (adequate fit) | |
| CFI | > .90 (adequate fit) | .944 |
| | > .95 (good fit) | |
| NFI | > .90 (adequate fit) | .894 |
| | > .95 (good fit) | |
| TLI | > .90 (adequate fit) | .934 |
| | > .95 (good fit) | |

The structural model explained 48 percent of the variance of the stage of change variable, 25 percent of the variance of the decisional balance variable, and 30 percent of the variance in the perceived compatibility variable. Only 9 percent of the variance was explained in the perceived ease of use variable. The communications behavior variable was not useful in explaining the variance for the precision agriculture self-efficacy variable. The variance explained for precision agriculture self-efficacy variable was less than 1 percent. Table 29 shows the variance explained in the endogenous variables.

*Table 29*

Variance Explained in Endogenous Variables

| Variable | Variance Explained (percent) |
|---|---|
| Self-efficacy | 0.8 |
| Ease of Use | 9.1 |
| Compatibility | 30.5 |
| Decisional Balance | 24.9 |
| Stage of Change | 47.6 |

## Path Analyses and Hypotheses Testing Using Structural Equation Modeling

Structural equation modeling using AMOS was used to test the hypotheses by evaluating the significance of the path coefficients. Table 30 summarizes the hypotheses tested and presents the standardized coefficients for each of the paths so that the reader may clearly see the magnitude of any relative differences. 48 percent of the variance of the stage of change variable was explained by the structural model.

Support was present for H1a which stated that decisional balance predicted stage of change. The standardized path coefficient was .140 ($p = .008$). As stated earlier, H1b was supported in that pros were positively correlated with stage (r =. 426,

$p < .001$). Contrary to H1c, cons were positively correlated with stage ($r = .186$, $p = .003$).

Perceived compatibility also directly affected stage of change, supporting H2a. The path coefficient representing the perceived compatibility to stage of change path was .555 ($p < .001$). The path from precision agriculture self-efficacy to stage of change was not significant, thus H4a was not supported ($\beta = .070$, $p = .119$). Farm size affected stage of change ($\beta = .213$, $p < .001$), supporting H6. Neither education level nor off farm employment was a significant factor in affecting stage of change ($\beta = -.063$, $p = .171$; $\beta = .093$, $p = .076$); thus H7 and H8 were not supported.

Perceived ease of use directly affected the decisional balance ($\beta = .153$, $p = .033$), supporting H3a. Although self-efficacy did not have a direct effect on stage of change (H4a, $\beta = .070$, $p = .187$), self-efficacy had an indirect influence on stage of change through decisional balance and perceived ease of use. The path from perceived ease of use to decisional balance ($\beta = .143$, $p = .029$) was significant, supporting H4b. Additionally, precision agriculture self-efficacy indirectly affected decisional balance through perceived ease of use. The path from precision agriculture self-efficacy to ease of use ($\beta = .301$, $p < .001$) was significant. Thus, H4c was supported. This finding is comparable to the Adrian et al. (2005) study which found that confidence in using

*Table 30*

Hypotheses and Path Results

| # | Hypothesis | Path Standardized Regression Weight | p – level | Critical Ratio | Hypothesis (Support / Not Supported) |
|---|---|---|---|---|---|
| H1a | Decisional balance predicts stage of change. | .140 | .008 | 2.657 | Supported |
| H1b | Pros are positively correlated with stage of change. | .426* | .000* | -- | Supported |
| H1c | Cons are negatively correlated with stage of change. | .186* | .003* | -- | Not Supported |
| H2a | The perceived compatibility of precision agriculture positively influences stage of change. | .555 | <.001 | 10.308 | Supported |
| H2b | The perceived compatibility of the precision agriculture positively influences decisional balance. | .344 | <.001 | 5.054 | Supported |
| H3a | The perceived ease of use of precision agriculture technologies positively influences decisional balance. | .153 | .033 | 2.129 | Supported |
| H3b | The perceived ease of use of precision agriculture technologies positively influences perceived compatibility. | .540 | <.001 | 8.895 | Supported |
| H4a | Precision agriculture self-efficacy positively influences stage of change. | .070 | .187 | 1.318 | Not Supported |

* Correlations were reported in correlation statistics prior to the analysis of the structural model.

Table 30 Continued

| | | | | | |
|---|---|---|---|---|---|
| H4b | Precision agriculture self-efficacy positively influences decisional balance. | .143 | .029 | 2.187 | Supported |
| H4c | Precision agriculture self-efficacy positively influences perceived ease of use. | .301 | <.001 | 3.890 | Supported |
| H5a | Communications behaviors positively influence precision agriculture self-efficacy. | .089 | .194 | 1.299 | Not Supported |
| H5b: | Communications behaviors positively influence perceived compatibility. | .102 | .060 | 1.874 | Not Supported |
| H6: | Farm size positively influences stage of change. | .213 | <.001 | 4.681 | Supported |
| H7: | Education level positively influences stage of change. | -.068 | .133 | -1.502 | Not Supported |
| H8: | Off-farm employment positively influences stage of change. | .076 | .093 | 1.680 | Not Supported |

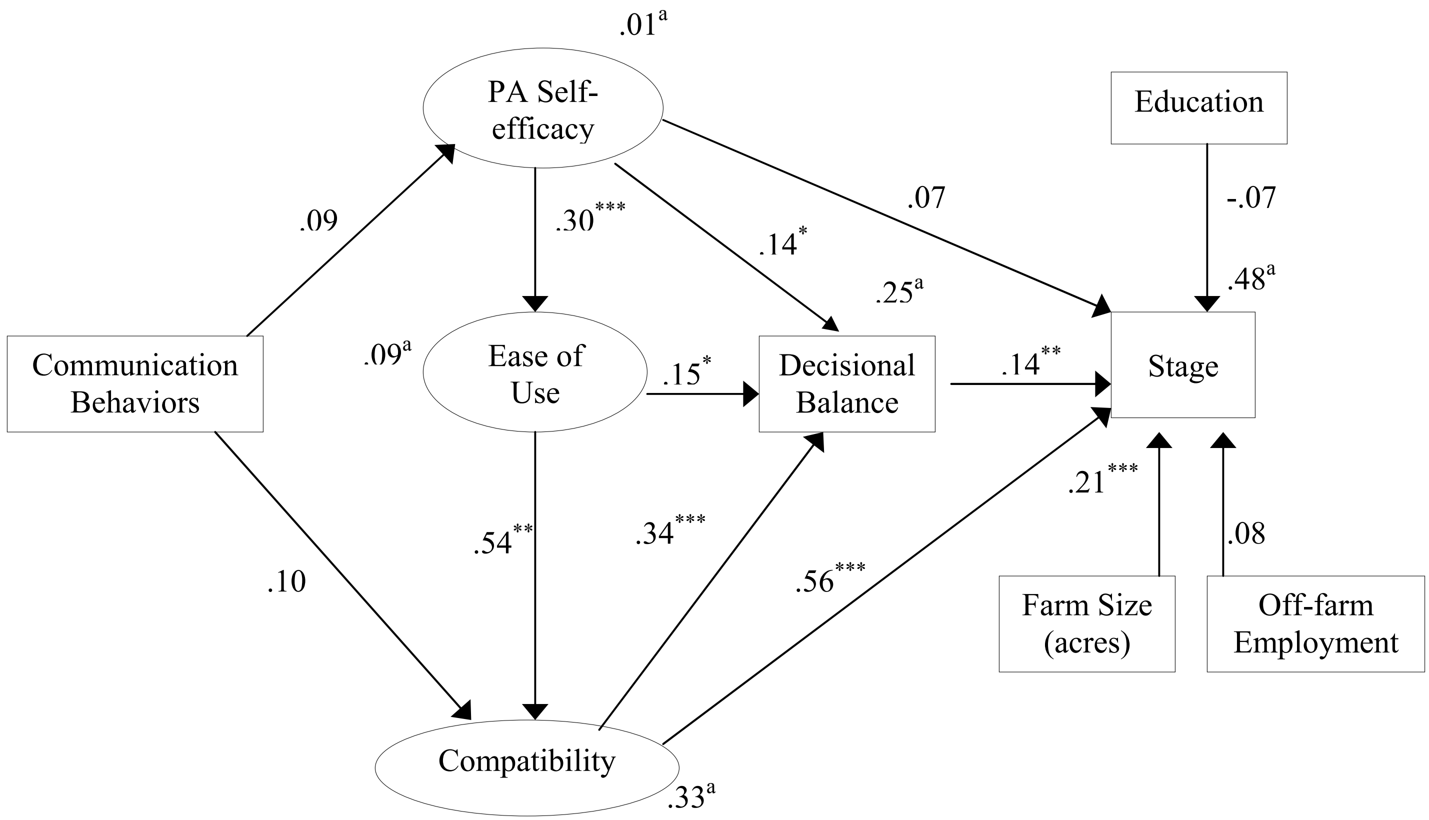


Figure 13. Structural equation model standardized regression weights and variance

*p-level < .05; **p-level <. 01 ; ***p-level < .001; [a] variance explained for endogenous variable.

precision agriculture influenced the perception of ease of use. In their study, the confidence scale was adapted from a computer confidence scale (Loyd & Gressard, 1984).

Not only did perceived compatibility directly influence stage of change, but it also influenced decisional balance ($\beta = .344$, $p < .001$), thus supporting H2b. Perceived compatibility influenced stage of change directly and indirectly through decisional balance. Perceived ease of use was found to also affect perceived compatibility ($\beta = .540$, $p < .001$), thus supporting H3b. The communications behavior variable was not found to be significant for precision agriculture self-efficacy ($\beta = .095$, $p = .191$), nor was it significant for the perceived compatibility variable ($\beta = .102$, $p = .060$). Thus, H5a and H5b were not supported.

These results indicated that producers with higher levels of perceived compatibility and perceived ease of use will have higher levels of decisional balance. The stage of change construct was directly influenced by compatibility and decisional balance. Stage of change was indirectly affected by compatibility and ease of use through decisional balance. Although precision agriculture self-efficacy did not directly affect decisional balance, it was an important construct because self-efficacy did influenced perceived ease of use.

Because the coefficients of the paths are standardized, a comparison of the coefficients indicates the degree for which paths contribute to the endogenous variables. For instance, the path from perceived compatibility to decisional balance was .344 ($p < .001$) and the path from ease of use to decisional balance was .153

($p = .033$), thus compatibility seemed to contribute almost twice as much to decisional balance than perceived ease of use. Similarly, the path coefficient from compatibility to stage of change .555 ($p < .001$) was more than twice of the path coefficient from farm size to stage of change ($\beta = .213$, $p < .001$). This result indicated that perceived compatibility may be more important to the stage of change than farm size, although both were important contributing factors.

## Summary

The purpose of this research is to create a model that describes, explains, and predicts the stage of change associated with the precision agriculture adoption-decision process. The proposed model described in Figure 2 and the hypotheses described in Table 1 were tested by using structural equation modeling. Decisional balance predicted stage of change. Farm size and compatibility with operations and style of farming also directly influenced stage of change. Factors that indirectly affected stage of change were perceived ease of use and precision agriculture self-efficacy.

Communications behavior, educational level, and off-farm employment did not contribute to the model significantly. These results imply that the model was effective in predicting stage of change and decisional balance.

# CHAPTER 5

# DISCUSSION

Very little attention has been given to the perceptions and attitudinal reasons farmers adopt precision agriculture technologies (Adesina & Baidu-Forson, 1995; Cochrane, 1993). By evaluating the perceptions and attitudes of farmers, researchers and practitioners can begin to understand why farmers adopt technologies and what industry and researchers may focus on to affect adoption of these technologies.

This research used a multidisciplinary approach to develop a model that explained some of the factors that influence the intention to use precision agriculture technologies. This model was derived from the Transtheoretical Model (Prochaska & Norcross, 2001; Prochaska et al., 1988), the Technology Acceptance Model's ease of use subscale (Davis, 1989), Moore and Benbasat's (1991) compatibility scale, and Hill's et al. (1987) self-efficacy scale. The decisional balance variable was developed using the publicized advantages and disadvantages of the precision agriculture.

This study empirically tested how the effects of the perceived advantages and disadvantages of precision agriculture, perceived ease of use, perceived compatibility, and precision agriculture self-efficacy affected the stage of change associated with the adoption of precision agriculture. Additionally, farm size, educational level, and off-farm employment were tested for the effects on the stage of change.

## Review of Results

Confirmatory factor analysis and structural equation modeling were used to test the hypothesized model. The results indicated that the model fit the data adequately. Decisional balance, compatibility, and farm size directly influenced stage of change. Perceived ease of use, perceived compatibility, and precision agriculture self-efficacy affected decisional balance. Precision agriculture self-efficacy affected perceived ease of use and decisional balance and indirectly stage of change. Communications behavior did not affect precision agriculture self-efficacy and perceived compatibility. Educational level and off-farm employment did not influence stage of change.

While decisional balance and farm size were influential in explaining the stage of change, compatibility showed a very strong influence on stage of change and on decisional balance. These results confirm the notion that individuals will accept change if they think it is compatible with their operations and goals (Armenakis & Harris, 2002; Chau & Hu, 2002; Moore & Benbasat, 1991; Rogers, 1995). The standardized path coefficient for perceived compatibility to stage of change was more than twice of the standardized path coefficient from farm size to stage. The standardized path coefficient from perceived compatibility to stage of change was more than three times the standardized path coefficient from decisional balance to stage of change. This comparison indicated that cognitive perceptions of costs and benefits and perceptions of the technologies are important in the stage of change. This comparison verified the opinions that factors other than economic benefit are important to farmers making the decision to use precision agriculture (Cochrane, 1993; Vanclay, 1992). Likewise, the factors that determine the decisional balance were found to be perceived ease of use, perceived compatibility, and precision agriculture self-efficacy.

## Implications

The proposed stage of change model associated with the precision agriculture expands our knowledge of precision agriculture use by examining perceptions and attitudes toward precision agriculture tools. The results of this study are important to test existing psychology and information systems concepts within the agricultural industry. This research also helps us understand that factors, other than perceived economic benefit, are important in making the decision to use precision agriculture technologies.

Figure 14 demonstrates the effects of the attitudes and perceptions of farmers' decisions to use precision agriculture technologies. At the beginning of the continuum is the early stage of change. The typical farmer in the early stage of change is not interested in adopting precision agriculture. These farmers belong to one of two groups. One group includes those who have made a deliberate decision to not adopt, even though they understand some of the benefits. The other group who has no intention in adopting are those who are either not aware of the technologies or that they have not given much consideration to adopt precision agriculture.

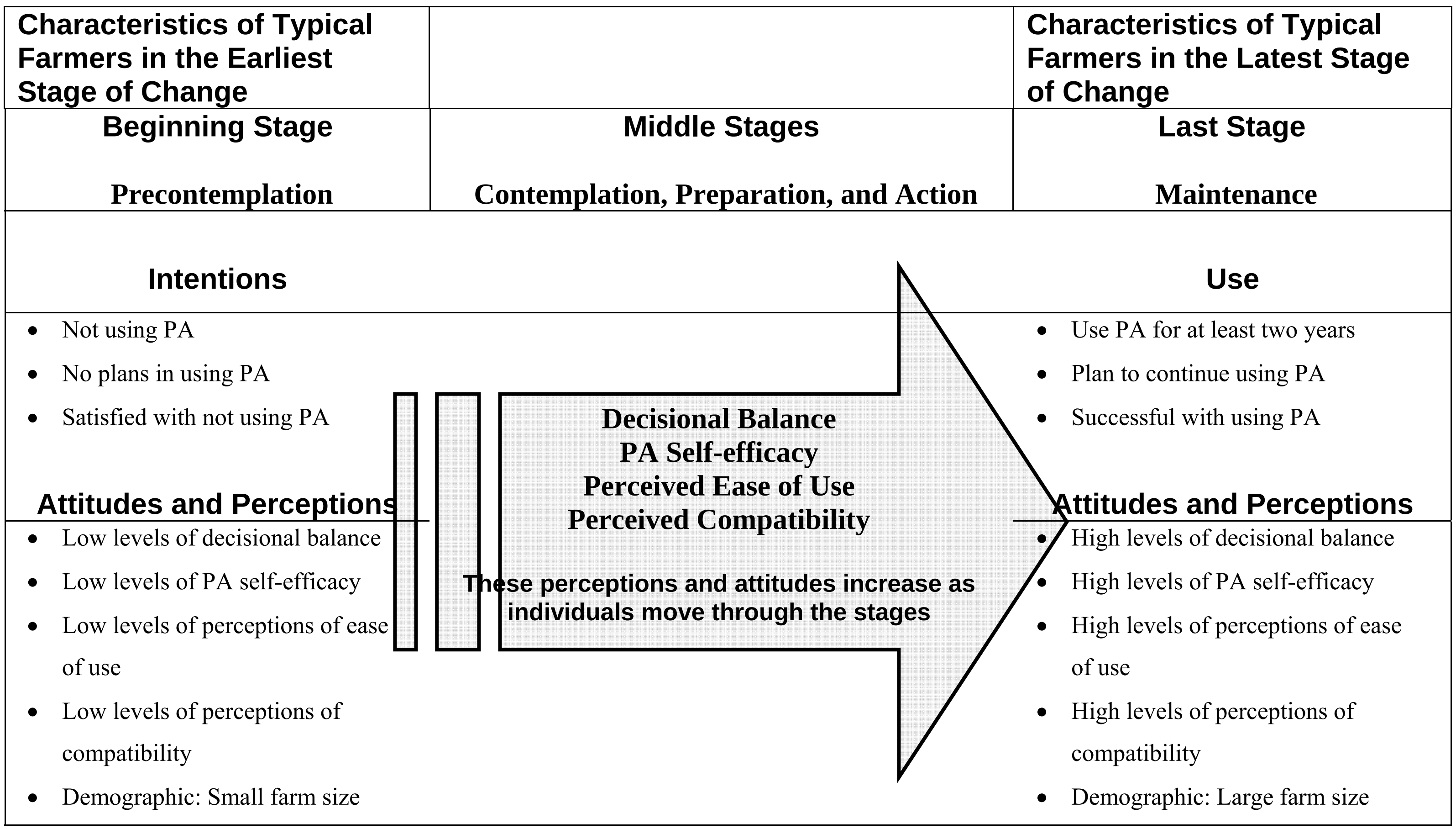


Figure 14. Stage of change continuum

As an individual moves from the earliest stage through the middle stages and into the latest stage, each attitude increases. The pivotal decisional point is the decisional balance construct. As farmers believe the advantages outweigh the disadvantages of using precision agriculture, they move further along in the stages of change.

On the end of the continuum is the maintenance stage. These farmers have used precision agriculture for at least two years and plan to continue. These farmers typically perceive the precision agriculture as easy to use and compatible with their operations and practices. They also have confidence in their abilities to use precision agriculture technologies. They weigh the importance of advantages greater than the disadvantages, in terms of importance. They will also manage large farms.

The stage of change model can be used as a basis to study the adoption of other technological advancements. This study used established constructs adapted to the precision agriculture context to analyze the relationship between perceptions and attitudes and the intention to use precision agricultural tools.

## Limitations

The results and contributions of this study should be evaluated by considering the limitations of the study. One limitation of this study is that the generalizability of the results is limited to row crop farmers in Alabama. Because of differences in production practices among agricultural producers, generalizing these results should be limited to row crop farmers in the southeastern United States with farms over 50 acres.

Another limitation is that the study is a cross-sectional study. This study did not examine whether intention actually predicts precision agriculture use. For those farmers who intend to use precision agriculture within the next two years, a longitudinal study could validate intention and use. Furthermore, this study used only self-report measures. Correlating actual use and stage of change measures over a particular time period could strengthen the study and our understanding of the behavior and intention of potential precision agriculture adopters.

No economic measures were used to indicate that precision agriculture actually improves the economic status of the farm. Linking economic benefit to actual use was beyond the scope of this study. However, correlating the perceptions of precision agriculture, stage of change, actual use, and economic improvement over a time period could expand researchers' and practitioners' understanding of use and benefit of these technologies.

Contributing to the decisional balance is the perception that precision agriculture is compatible with the farming operations and practices. The perception of compatibility is an important area for change agents to understand because the perception of compatibility leads directly to influencing the stage of change, but also indirectly through the decisional balance. Focusing on the goals of the farmers, change agents and vendors should demonstrate how these tools can help farmers use precision agriculture tools meet their goals. Change agents should demonstrate how these tools work and how they integrate with existing equipment. Thus, the perception of compatibility with farming practices and operations should increase, thus increasing the level of decisional balance and moving the farmer to a later stage of change. Support has been found that demonstration of agricultural practices and technologies helps change the practices and technology use among agricultural producers (Heiniger, Havlin, Crouse, Kvien, & T., 2002).

The perception of ease of use contributes to both the decisional balance and the perception of compatibility with farming operations and practices. Focusing on complexity issues may help farmers better understand the technology; thus, increasing the perceptions of ease of use. As the levels of perceptions of ease of use increase, so will the levels of the perception of compatibility. Furthermore, high levels of precision agriculture self-efficacy lead to perceptions that precision agriculture technologies are easy to use and are beneficial, increasing the decisional balance. Change agents should consider targeting educational efforts in helping farmers become comfortable with precision agriculture technologies.

## Future Research

Although the findings of these results provide valuable insight into what factors are considered when farmers make the decision to use precision agriculture technologies, there are several areas where future research would be beneficial. One point of interest is that there was no significant relationship found between communication behaviors and self-efficacy and communications behaviors and compatibility. This study used a measure of communications behaviors as the average of the frequency of use of various informational sources.

The communication behaviors variable did not contribute to the model as posited by Rogers (1995). A consideration of particular types of communications behavior may be more explanatory. Rather than using the frequency of use of several information sources, the type of source of information may be more important in explaining differences in self-efficacy and compatibility. For instance, those who used information from Internet sources or from professional sources, like Extension and University staff and agribusiness vendors, may have the propensity to see precision agriculture as compatibility with their operations and goals. Conversely, the use of mass media sources may not indicate a relevant relationship to compatibility.

Additionally, the low level of variance explained in self-efficacy and ease of use suggests that other variables may contribute to these factors. Further development of additional constructs, such as managerial abilities, could also lead to a better understanding and motivations and capabilities of farmers. For example, do managerial abilities make differences in precision agriculture self-efficacy, perceived ease of use, and perceived compatibility? Also, do computer technical skills make a difference in these constructs? Understanding what factors are important in affecting precision agriculture self-efficacy would help change agents improve farmers' confidence in using precision agriculture technologies.

In spite of the overall support for the hypothesized model, there is still room for improvement. Decisional balance–the decision making construct—was created using publicized benefits and disadvantages. The pros subscale included 15 items and the cons subscale included 13 items. The reliability of these constructs was high, as expected, because the number of items would indicate high reliability (Hinkin, 1995). Furthermore, the error variance of several items was shared. The number of items and the shared error variance leads us to believe that the construct could be refined with a reduction of the items. Additionally, more parsimony pros and cons subscales should be developed to reduce respondent fatigue (Anastasi, 1986) and shorten the survey form.

The stage of change in this model was created using a continuous variable adapted from the Marcus et al., (1992) study. However, no specific values were specified to categorize stages of change. Although the categorical stage of change measure does provide stage specific values for each stage (Prochaska & Norcross, 2001; Prochaska et al., 1988), TTM researchers have not provided stage specifics in the use of the stage of change continuous variable (Marcus et al., 1992). More research is needed to specifically identify the stages.

A similar study using the categorical stage of change measure may help determine which form of stage of change variable would be better to use in this context. One advantage of the categorical scale is that it uses only a few items, rather than the 25 items used in this study. Thus, a categorical scale may be more parsimonious. However, it may not provide as much explanatory value.

The practical side of the TTM is to match intervention techniques to the stage of change. These interventions are based on the processes of change. As described in Chapter 2, these processes of change help individuals move through the stages of change. In clinical settings, the stage of change is determined and the intervention techniques are matched to the stage which then, in turn, helps individuals change behavior, moving them through the stages of change. Before a determination of which interventions would be effective for each of the stages, the processes of change, as described in Chapter 2, should be tested in the precision agriculture context.

Despite a plethora of IS studies on use of information technologies, the TTM and a comprehensive decision-making construct have not been used in the IS field of research. This stage of change model could be adapted for adoption of information technologies within organizations. A decisional balance construct should be developed that is appropriate for the technology being studied. Additionally, the target behavior and a time-frame associated with the intention of adoption should be defined as well. It is likely that the target behavior for using a technology within an organization would be different than using precision agriculture.

## Summary

This study investigated factors that affect the decision to use precision agriculture tools. The theoretical model developed and tested the mediating roles of decisional balance, perceived compatibility perceived ease of use, and self-efficacy. The findings suggest that these factors are important in predicting the stage of change. These findings are important because they offer tangible evidence that these factors are important in making the decision to use precision agriculture.

REFERENCES

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: Evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics, 13*, 1-9.

Adesina, A. A., & Zinnah, M. M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural Economics, 9*, 291-311.

Adrian, A. M., Dillard, C., & Mask, P. (2004). GIS in agriculture. In J. B. Pick (Ed.), *Geographic Information Systems in Business* (pp. 324-342). Hershey, PA: Idea Group Publishing.

Adrian, A. M., Norwood, S. H., & Mask, P. L. (2005). Producers' perceptions and attitudes toward precision agriculture technologies. *Computers and Electronics in Agriculture, 48*(3), 256-271.

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology, 22*, 453-474.

Anastasi, A. (1986). Evolving concepts of test validations. *Annual Review of Psychology, 37*, 1-15.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*, 411-423.

Armenakis, A., A., & Harris, S. G. (2002). Crafting a change message to create transformational readiness. *Journal of Organizational Science, 15*(2), 169-183.

Armenakis, A., A., Harris, S. G., & Feild, H. S. (1993). Creating readiness for organizational change. *Human Relations, 46*(3), 1-23.

Armenakis, A., A., Harris, S. G., & Feild, H. S. (1999). Making change permanent a model for institutionalizing change. In W. Pasmore & R. Woodman (Eds.), *Research in Organizational Change and Development* (Vol. 12, pp. 97-128). Greenwich, CT: JAI Press.

Armitage, C. J., Sheeran, P., Conner, M., & Arden, M. A. (2004). Stages of change or changes of stage? Predicting transitions in transtheoretical model stages in relation to healthy choice. *Journal of Consulting and Clinical Psychology, 72*(3), 491-499.

Atherton, B. C., Morgan, M. T., Shearer, S. A., Stombaugh, T. S., & Ward, A. D. (1999). Site-specific farming: A perspective on information needs, benefits, and limitations. *Journal of Soil and Water Conservation, 54*(2), 455-461.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Batte, M. (2005). Changing computer use in agriculture: Evidence from Ohio. *Computers and Electronics in Agriculture, 47*(1), 1-13.

Batte, M. T. (2000). Factors influencing the profitability. *Journal of Soil and Water Conservation, 55*(1), 12-20.

Batte, M. T., & Arnholt, M. W. (2003). Precision arming adoption and use in Ohio: Case studies of six leading-edge adopters. *Computers and Electronics in Agriculture, 38*, 125-139.

Batte, M. T., Pohlman, X., Forster, D. L., & Sohngen, B. (2003). *Adoption and Use of Precision Farming Technologies: Results of a 2003 Survey of Ohio Farmers* (No. AEDE-RP-0039-03). Columbus, Ohio: The Ohio State. Agriculture Education and Development Center.

Beal, G., E., Rogers, E. M., & Bohlen, J. (1957). Validity of the concept of stages in the adoption process. *Rural Sociology, 22*, 166-168.

Beal, G., & Rogers, E. M. (1960). *The adoption of two farm practices in a central Iowa community* (No. RSE). Ames, IA: Iowa Agricultural and Home Economics Experiment Station.

Bergeron, F., Raymond, L., & Rivard, S. (2001). Fit in strategic information technology management research: An empirical comparison of perspectives. *Omega International Journal of Management Science, 29*(2), 125-137.

Bollen, K. A. (1989). *Structural Equations with Latent Variables*. New York, NY: Wiley.

Bouma, J., Stoorvogel, J., van Alphen, B. J., & Booltink, H. W. G. (1999). Pedology, precision agriculture, and the changing paradigm of agricultural research. *Soil Science Society of America Journal, 63*(6), 1763-1768.

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing Structural Equation Models* (pp. 132-162). Beverly Hills, CA: Sage.

Browne, M. W., & Mels, G. (1992). *RAMONA Users Guide*. Columbus, Ohio: The Ohio State University.

Brynjolfsson, E., & Hitt, L. (1996). Paradox lost? Firm-level evidence on the returns to information systems spending. *Management Science, 42*(4), 541-558.

Byrne, B. M. (2001). *Structural Equation Modeling with AMOS Basic Concepts, Applications, and Programming*. Mahwah, NJ: Lawrence Erlbaum Associates.

Chan, Y. E., Huff, S. L., Barclay, D. W., & Copeland, D. G. (1997). Business strategic orientation, information systems strategic orientation, and strategic alignment. *Information Systems Research, 8*(2), 125-150.

Chau, P. Y. K. (2001). Influence of computer attitude and self-efficacy on IT usage behavior. *Journal of End User Computing, 13*, 27-33.

Chau, P. Y. K., & Hu, P. J. (2002). Examining a model of information technology acceptance by individual professionals: An exploratory study. *Journal of Management Information Systems, 18*(4), 191-229.

Chen, Y., & Zhu, J. (2004). Measuring information technology's indirect impact on firm performance. *Information Technology and Management, 5*(1-2), 9-22.

Churchill, G. A. (1979). A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research, 16*, 64-73.

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessments instruments in psychology. *Psychological Assessment, 6*(4), 284-290.

Coch, L., & French, J. (1948). Overcoming resistance to change. *Human Relations, 1*(4), 512-532.

Cochrane, W. (1993). *The Development of American Agriculture: A Historical Analysis*. Minneapolis, MN: University of Minnesota Press.

Coleman, J. S., Katz, E., & Menzel, H. (1966). *Medical Innovation: A Diffusion Study*. New York, NY: Bobbs-Merrill.

Compeau, D. R., & Higgins, C. A. (1995). Computer self-efficacy: Development of a measure and initial test. *MIS Quarterly, 19*, 189-211.

Cunningham, C. E., Woodward, C. A., Shannon, H. S., McIntosh, J., Lendrum, B., Rosenbloom, D., et al. (2002). Readiness for organizational change: A longitudinal study of workplace, psychological and behavioral correlates. *Journal of Occupational and Organizational Psychology, 75*, 377-392.

Daberkow, S. G., & McBride, W. D. (2003). Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. *Precision Agriculture, 4*, 163-177.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*, 319-339.

Davis, G., Cassady, W., & Massey, R. Precision Agriculture: An Introduction. In U. Extension (Ed.) (pp. 1-7): University of Missouri-System.

DiClemente, C. C., Prochaska, J. O., Fairhust, S. K., Velicer, W. F., Velasquez, M. M., & Rossi, J. S. (1991). The process of smoking cessation: An analysis of precontemplation, contemplation, and preparation stages of change. *Journal of Consulting and Clinical Psychology, 59*, 295-304.

DiClemente, C. C., Prochaska, J. O., & Gibertini, M. (1985). Self-efficacy and the stages of self-change of smoking. *Cognitive Therapy and Research, 9*(2), 181-200.

Downey, R. G. A. (1998). Missing data in Likert ratings: A comparison of replacement methods-method for measuring attitudes by R. Likert. *Journal of General Psychology, 125*(2), 175-191.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention and Behavior*. Reading, MA: Addison-Wesley.

Gist, M. E. (1987). Self-efficacy: Implications for organizational behavioral and human resource management. *Academy of Management Review, 12*, 472-485.

Godwin, R. J., Richards, T. E., Wood, G. A., Welsh, J. P., & Knight, S. M. (2003). An economic analysis of the potential for precision farming in UK cereal production. *Biosystems Engineering, 84*(4), 533-545.

Greenstein, D. K., Franklin, M. E., & McGuffin, P. (1999). Measuring motivation to change: An examination of the University of Rhode Island change assessment questionnaire (URICA) in an adolescent sample. *Psychotherapy, 36*(1), 47-55.

Heiniger, R. W., Havlin, J. L., Crouse, D. A., Kvien, C., & T., K. (2002). Seeing is believing: The role of field days and tours in precision agriculture education. *Precision Agriculture, 3*, 309-318.

Hill, T., Smith, N. D., & Mann, M. F. (1987). Role of efficacy expectations in predicting the decision to use advanced technologies: The case of computers. *Journal of Applied Psychology, 72*(2), 307-313.

Hinkin, T. R. (1995). A review of scale development practices in the study of organizations. *Journal of Management, 21*(5), 967-988.

Hoag, D. L., Ascough II, J. C., & Frasier, W. M. (1999). Farm computer adoption in the Great Plains. *Journal of Agricultural and Applied Economics, 31*, 57-67.

Hoag, D. L., Ascough II, J. C., & Frasier, W. M. (2000). Will farmers use computers for resource and environmental management? *Journal of Soil and Water Conservation, 55*(4), 456-461.

Howard, M. (1996). Technology helps farmers target and reduce chemicals. *Christian Science Monitor, 88*(248), 10.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*.

Hudson, D., & Hite, D. (2001). *Adoption of precision agriculture technology in Mississippi: Preliminary results from a producer survey* (No. 2001-001). Starkville, MS: Department of Agricultural Economics, Mississippi State University.

Hudson, D., & Hite, D. (2003). Willingness to pay for water quality improvements: The case of precision application technology. *Journal of Agricultural and Resource Economics, 27*, 433-449.

Igbaria, M., & Iivari, J. (1995). The effects of self-efficacy on computer usage. *Omega International Journal of Management Science, 23*, 587-605.

Intarapapong, W., Hite, D., & Hudson, D. (2003). *The economic and environmental impacts of variable rate application: The case of Mississippi* (Research Report No. Research Report 2002-2003). Starkville, Mississippi: Mississippi State University.

Isik, M., Khanna, M., & Winter-Nelson, A. (2000, 2000). *Sequential investment in site-specific crop management under output price uncertainty.* Paper presented at the 2000 International Precision Agriculture Conference.

Janis, I. L., & Mann, L. (1977). *Decision Making: A Psychological Analysis of Conflict, Choice, and Commitment*. New York, NY: Free Press.

Kettinger, W. J., Lee, C. C., & Lee, S. (1995). Perceived service quality and user satisfaction with the information services function. *Decision Sciences, 25*(5), 737-766.

Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: A double selectivity model. *American Journal of Agricultural Economics, 83*(1), 35-45.

Khanna, M., Isik, M., & Winter-Nelson, A. (2000). Investment in site-specific crop management under uncertainity: Implications for nitrogen pollution control and environmental policy. *Agricultural Economics, 24*, 9-21.

Kitchen, N. R., Snyder, C. J., Franzen, D. W., & Wiebold, W. J. (2002). Educational needs of precision agriculture. *Precision Agriculture, 3*, 341-351.

Lamar, R. V. (1966). In-service Education Needs Related to Diffusion on an Innovation (pp. 72): Berkeley, University of California.

Larkin, S. L., Perruso, L., Marra, M. C., Roberts, R. K., English, B. C., Larson, J. A., et al. (2005). Factors affecting perceived improvements in environmental quality from precision farming. *Journal of Agricultural and Applied Economics, 37*(3), 577-588.

Levesque, D., Prochaska, J. M., & Prochaska, J. O. (1999). Stages of change and integrated delivery service. *Consulting Psychology Journal: Practice and Research, 51*(4), 226-241.

Levesque, D., Prochaska, J. M., & Prochaska, J. O. (2001). Organizational stages and processes of change for continuous quality improvement in health care. *Consulting Psychology Journal: Practice and Research, 53*(3), 139-153.

Lowenberg-DeBoer, J. (1996). Precision farming and the new information technology: Implications for farm management, policy, and research: Discussion. *American Journal of Agricultural Economics, 78*, 1281-1284.

Lowenberg-DeBoer, J. (1999). Risk management potential of precision farming technologies. *Journal of Agricultural and Applied Economics, 31*, 275-285.

Loyd, B. H., & Gressard, C. (1984). Reliability and factorial validity of computer attitude scales. *Educational and Psychological Measurement, 44*, 501-505.

Marcus, B. H., Selby, V. C., Niaura, R. S., & Rossi, J. S. (1992). Self-efficacy and the stages of exercise behavior change. *Research Quarterly for Exercise and Sport, 63*, 60-66.

Markus, M. L., & Robey, D. (1988). Information technology and organizational change, causal structure in theory and research. *Management Science, 34*(5), 583-598.

Marshall, S. J., & Biddle, S. J. H. (2001). The transtheoretical model of behavior change: A meta-analysis of applications to physical activity and exercise. *Annals of Behavioral Medicine, 23*(4), 229-246.

McConnaughy, E. A., DiClemente, C. C., Prochaksa, J., & Velicer, W. F. (1989). Stages of change in psychotherapy: A follow-up report. *Psychotherapy, 26*, 494-503.

McConnaughy, E. A., Prochaksa, J., & Velicer, W. F. (1983). Stages of change in psychotherapy: Measurement and sample profiles. *Psychotherapy, 20*, 368-373.

Milbrath, Y. L., & Kinzie, M. B. (2000). Computer technology training for perspective teachers: Computer attitudes and perceived self-efficacy. *Journal of Technology and Teacher Education, 8*, 373- 375.

Moore, G., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research, 2*, 192-222.

Napier, T., Robinson, J., & Tucker, M. (2000). Adoption of precision farming with three Midwest watersheds. *Journal of Soil and Water Conservation, 55*(2), 135-147.

National Research Council. (1997). *Precision Agriculture in the 21st Century: Geospatial and Information Technologies in Crop Management*. Washington, D. C.: National Academy Press.

Necessary, J. R., & Parish, T. S. (1996). The relationship between computer usage and computer related- attitudes and behaviors. *Education, 116*, 384-386.

Nunnally, J. C. (1978). *Psychometric Theory* (2nd ed.). New York: McGraw-Hill.

Olson, K. (1998). *Sixth Joint Conference Food, Agriculture, and the Environment*: Center for International Food and Agricultural Policy, University of Minnesota.

Orr, C., Allen, D., & Poindexter, S. (2001). The effect of individual differences on computer attitudes: an empirical study. *Journal of End User Computing, 13*, 26-40.

Precision Ag. (2005, March 2005). Precision ag starting to catch on in South. *Cotton Farming,* 6.

Prochaksa, J., DiClemente, C. C., & Norcross, J. C. (1992). In search of how people change: Applications to addictive behaviors. *American Psychologist, 47*(9), 1102-1114.

Prochaska, J. M., Levesque, D. A., Prochaska, J. O., Dewart, S. R., & Wing, G. R. (2001). Mastering change: A core competency for employees. *Brief Treatment and Crisis Intervention, 1*(1), 7-15.

Prochaska, J. M., Prochaska, J. O., & Levesque, D. (2001). A transtheoretcal approach to changing organizations. *Administration and Policy in Mental Health, 28*(4), 247-261.

Prochaska, J. O. (1994). Strong and weak principles for progressing from precontemplation to action on the basis of 12 problem behaviors. *Health Psychology, 13*, 47-51.

Prochaska, J. O., & Norcross, J. C. (2001). Stages of change. *Psychotherapy, 38*(4), 443-448.

Prochaska, J. O., Velicer, W. F., DiClemente, C. C., & Fava, J. (1988). Measuring processes of change: Applications to the cessation of smoking. *Journal of Consulting and Clinical Psychology, 56*, 520-528.

Rainer, R. K., Jr., & Miller, M. D. (1996). An assessment of the psychometric properties of the computer attitude scale. *Computer in Human Behavior, 12*, 93-105.

Reed, G. R. (1994). Measuring stage of change for exercise behavior change, URICA-E2. Unpublished Dissertation.

Rejesus, R. M., & Hornbaker, R. H. (1999). Economic and environmental evaluation of alternative pollution-reducing nitrogen management practices in central Illinois. *Agriculture, Ecosystems and Environment, 75* (1), 41-54.

Rogers, E. M. (1983). *Diffusion of Innovations* (3rd ed.). New York, NY: The Free Press.

Rogers, E. M. (1995). *Diffusion of Innovations* (4th ed.). New York. NY: The Free Press.

Rosen, C. S. (2000). Is the sequencing of change processes by stage consistent with health problems? A meta-analysis. *Health Psychology, 19*, 593-604.

Roth, P. L. (1994). Missing data: A conceptual review for applied psychologists. *Personnel Psychology, 47*(3), 537-560.

Sawyer, J. (1994). Concepts of variable rate technology with considerations for fertilizer applications. *Journal of Production Agriculture, 7*, 195-201.

Segars, A. H., & Grover, V. (1993). Re-examining perceived ease of use and usefulness: A confirmatory factor analysis. *MIS Quarterly, 17*(4), 517-525.

Smith, A., Morrison, P., Goe, W. R., & Kenny, M. (2004). *Computer and Internet Use by Great Plains Farmers* (No. 04-010): University of California, Davis.

Sonka, S. (1998, Retrieved May 23, 2003, 1998). *Precision agriculture as a priority.* Paper presented at the 2nd National Stakeholder Symposium, Washington D.C.

Sonka, S. T., & Coaldrake, K. F. (1996). Cyberfarm: What does it look like? What does it mean? *American Journal of Agricultural Economics, 78*, 1263-1266.

Swinton, S. M., & Lowenberg-DeBoer, J. (1998). Evaluating the profitability of site-specific farming. *Journal of Production Agriculture, 11*(4), 439-446.

Swinton, S. M., Marsh, S. B., & Ahmad, M. (1997). *Whether and How to Invest in Site-Specific Crop Management: Results of Focus Group Interviews in Michigan* (No. 96-37). East Lansing, MI: Department of Agricultural Economics, Michigan State University.

Vanclay, F. (1992). Barriers to adoption: A general overview of the issues. *Rural Society, 2*(2), 10-12.

Velicer, W. F., DiClemente, C. C., Prochaksa, J., & Brandenburg, N. (1985). Decisional balance measure for assessing and predicting smoking status. *Journal of Personality and Social Psychology, 48*(5), 1279-1289.

Velicer, W. F., Norman, G. J., Fava, J. L., & Prochaska, J. O. (1999). Testing 40 predictions from the transtheoretical model. *Addictive Behaviors, 24*, 455-369.

Venkatesh, V. (2000). Determinants of perceived ease of use: integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information Systems Research, 11*(4), 342-365.

Weinstein, N. D., Rothman, A., J., & Sutton, S. R. (1998). Stage theories of health behavior: Conceptual and methodological issues. *Health Psychology, 17*(3), 290-299.

Wheaton, B., Muthen, B., Alwin, D., & Summers, G. (Eds.). (1977). *Assessing reliability and stability in panel models*. San Francisco, CA: Jossey-Bass.

Wiebold, B., Sudduth, K., Davis, G., Shannon, K., & Kitchen, N. *Determining barriers to adoption and research needs of precision agriculture*. Missouri Precision Agriculture Center, University of Missouri and USDA/ARS.

Wolf, S. A., & Buttel, F. H. (1996). The political economy of precision farming. *American Journal of Agriculture Economics, 78*, 1269-1275.

APPENDICES

# Appendix A

## Cover Letter for the Survey Instrument

Dear Producer:

Did you know that Alabama has shown a slower rate of adoption of precision agriculture tools than most other states? Precision agriculture involves collecting field and crop information as they vary throughout fields and linking this varying information to field locations to determine and apply the appropriate and varying input levels.

Anne Mims Adrian is conducting a survey as part of her requirements to complete a doctorate in Management Information Systems. The purpose of Anne's research is to investigate the factors that influence farmers' decisions to adopt and use precision agriculture technologies. Regardless of whether you use precision agriculture, please take 10 to 15 minutes to complete this survey. It is only four pages long.

Answering this survey is voluntary and your response serves as an informed consent to participate in the study. Although you are under no obligation to complete the survey, your participation could possibly help researchers, Extension specialists and agents, and practitioners develop better precision agriculture educational programs and products. If you decide to participate, please complete each question to your best knowledge.

Any information obtained in this study is anonymous. We assure you that the responses will not be published or communicated in any way that could possibly identify you with the responses. Collectively, information gathered from you and other respondents may be used to fulfill an educational requirement, published in a dissertation, published in a professional journal, and presented at a professional meeting. You may withdraw from participation at any time by not completing the survey. However, whatever information is completed may be used in this study.

Your decision whether or not to participate will not jeopardize your future relations with Auburn University or the Alabama Cooperative Extension System. If you have any questions, feel free to call or email Anne Adrian (334 844 3507 or aadrian@auburn.edu) or her dissertation advisor, Dr. Kelly Rainer, Privett Professor, Department of Management, College of Business, 334 844 4071, rainerk@auburn.edu.

For more information regarding your rights as a research participant you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334) 844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@auburn.edu.

Sincerely,

W. Gaines Smith
Interim Director
Alabama Cooperative Extension System
wsmith@aces.edu

Anne Mims Adrian, Co-Leader
Computer Technology Unit
Alabama Cooperative Extension System
PhD student, Department of Management
Auburn University

Appendix B

Survey Instrument

ALABAMA COOPERATIVE **Extension** SYSTEM *Your Experts for Life*

# Precision Agriculture Use Survey

Auburn University College of Agriculture

**November 2005**

**Section 1: Farming Operation**

1. Which of the following best describes you? Please **check** one.
   ____ I farm full-time. ____ I farm part-time. ___ I do not farm.

2. Of the total land you operate, how many acres are used to grow row crops? **Number of Acres**: ____________

3. Of the total land you operate, how many acres are used to grow:
   Corn? _____ acres Cotton? _____ acres Soybeans? _____ acres
   Peanuts? _____ acres Wheat? _____ acres Other? _____ acres

**Section 2: How frequently do you refer to the following sources for agricultural production, practices, and management? Circle one for each source.**

Not at all 1 · Infrequently 2 · Not Infrequent nor Frequent 3 · Frequently 4 · Very Frequently 5

| | Source | Not at all | | | | Very Frequently |
|---|---|---|---|---|---|---|
| 4. | University Extension Agents, Specialists, or Representatives | 1 | 2 | 3 | 4 | 5 |
| 5. | University Extension/Research Newsletters, Publications | 1 | 2 | 3 | 4 | 5 |
| 6. | Other Farmers | 1 | 2 | 3 | 4 | 5 |
| 7. | Agribusiness Vendors | 1 | 2 | 3 | 4 | 5 |
| 8. | Production Magazines | 1 | 2 | 3 | 4 | 5 |
| 9. | TV News | 1 | 2 | 3 | 4 | 5 |
| 10. | Radio | 1 | 2 | 3 | 4 | 5 |
| 11. | Newspapers | 1 | 2 | 3 | 4 | 5 |
| 12. | Internet Resources | 1 | 2 | 3 | 4 | 5 |
| 13. | Email Group/Lists | 1 | 2 | 3 | 4 | 5 |

**Section 3: How important are the following sources for agricultural production, practices, and management? Circle one for each source.**

Not at all important 1 · Not important 2 · Neither 3 · Important 4 · Very Important 5

| | Source | Not at all | | | | Very Important |
|---|---|---|---|---|---|---|
| 14. | University Extension Agents, Specialists, or Representatives | 1 | 2 | 3 | 4 | 5 |
| 15. | University Extension/Research Newsletters, Publications | 1 | 2 | 3 | 4 | 5 |
| 16. | Other Farmers | 1 | 2 | 3 | 4 | 5 |
| 17. | Agribusiness Vendors | 1 | 2 | 3 | 4 | 5 |
| 18. | Production Magazines | 1 | 2 | 3 | 4 | 5 |
| 19. | TV News | 1 | 2 | 3 | 4 | 5 |
| 20. | Radio | 1 | 2 | 3 | 4 | 5 |
| 21. | Newspapers | 1 | 2 | 3 | 4 | 5 |
| 22. | Internet Resources | 1 | 2 | 3 | 4 | 5 |
| 23. | Email Group/Lists | 1 | 2 | 3 | 4 | 5 |

## Section 4: For each precision agriculture tool that is listed below, please indicate your knowledge of these tools (not whether you have used them). Circle one for each tool.

| Never heard of this tool | Heard of this tool, but do not know what it is | Heard about this tool and know a little about it | Know what this tool is, but do not know how it is used or how to use it | Know what this tool is and how it is used, but do not know how to use it | Know what this tool is, how it is used, and how to use it |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 24. Grid or zone soil sampling with GPS | 0 | 1 | 2 | 3 | 4 | 5 |
| 25. Yield monitor with GPS | 0 | 1 | 2 | 3 | 4 | 5 |
| 26. Variable rate application (fertilizer, insecticide, seeding & defoliation) | 0 | 1 | 2 | 3 | 4 | 5 |
| 27. Remote sensing | 0 | 1 | 2 | 3 | 4 | 5 |
| 28. GIS computer system (mapping software) | 0 | 1 | 2 | 3 | 4 | 5 |
| 29. Lightbar | 0 | 1 | 2 | 3 | 4 | 5 |
| 30. Autoguidance system (for example, auto steer equipment) | 0 | 1 | 2 | 3 | 4 | 5 |

## Section 5: Please rank your intention to use these precision agriculture tools. If you do not know what the tool is, mark 0. The term "use" defines that the tool has been used on your farm, either by you or a consultant / Extension representative. Circle one for each tool.

| Never heard of this tool. | Some knowledge of this tool, but do not intend to use this tool in the foreseeable future. | Intend to use this tool in the foreseeable future, but not within the next year. |
|---|---|---|
| 0 | 1 | 2 |
| Intend to use this tool within the next year. | Used this tool for less than 2 years. | Used this tool for more than 2 years. |
| 3 | 4 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 31. Grid or zone soil sampling with GPS | 0 | 1 | 2 | 3 | 4 | 5 |
| 32. Yield monitor with GPS | 0 | 1 | 2 | 3 | 4 | 5 |
| 33. Variable rate application (fertilizer, insecticide, seeding, & defoliation) | 0 | 1 | 2 | 3 | 4 | 5 |
| 34. Remote sensing | 0 | 1 | 2 | 3 | 4 | 5 |
| 35. GIS (mapping software) | 0 | 1 | 2 | 3 | 4 | 5 |
| 36. Lightbar | 0 | 1 | 2 | 3 | 4 | 5 |
| 37. Autoguidance system (for example, auto steer equipment) | 0 | 1 | 2 | 3 | 4 | 5 |

## Section 6: Please rank the level that is most appropriate for which you agree or disagree. Circle one for with each statement.

| Strongly Disagree | Disagree | Undecided | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| | Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|---|
| 38. I will never understand how to use precision agriculture tools. | 1 | 2 | 3 | 4 | 5 |
| 39. Only a few experts really understand how precision agriculture tools work. | 1 | 2 | 3 | 4 | 5 |
| 40. It is extremely difficult to learn how to use precision agriculture tools. | 1 | 2 | 3 | 4 | 5 |
| 41. Precision agriculture errors are difficult to fix. | 1 | 2 | 3 | 4 | 5 |
| 42. Precision agriculture is compatible with all aspects of my farm operation. | 1 | 2 | 3 | 4 | 5 |
| 43. Precision agriculture is completely compatible with my current farming situation. | 1 | 2 | 3 | 4 | 5 |
| 44. Using precision agriculture fits well with the way I like to farm. | 1 | 2 | 3 | 4 | 5 |
| 45. Using precision agriculture fits with my farming style. | 1 | 2 | 3 | 4 | 5 |
| 46. Learning to operate precision agriculture tools is easy for me. | 1 | 2 | 3 | 4 | 5 |
| 47. I find it is easy to get precision agriculture tools to do what I want them to do. | 1 | 2 | 3 | 4 | 5 |
| 48. It is easy for me to remember how to perform tasks using precision agriculture tools. | 1 | 2 | 3 | 4 | 5 |
| 49. The use of precision agriculture tools is clear and understandable. | 1 | 2 | 3 | 4 | 5 |
| 50. I find precision agriculture tools to be flexible to work with. | 1 | 2 | 3 | 4 | 5 |
| 51. It is easy for me to become skillful at using precision agriculture tools. | 1 | 2 | 3 | 4 | 5 |
| 52. I find precision agriculture tools easy to use. | 1 | 2 | 3 | 4 | 5 |

| Section 7: Please rank the following statements to the extent of your agreement. Circle one for each statement. | | | | | |
|---|---|---|---|---|---|
| Strongly disagree 1 | Disagree 2 | Undecided 3 | Agree 4 | Strongly Agree 5 | |

| | Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|---|
| 53. As far as I'm concerned, I do not need to use precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 54. I have been using precision agriculture for a long time and I plan to continue. | 1 | 2 | 3 | 4 | 5 |
| 55. I don't use precision agriculture right now and I don't care to. | 1 | 2 | 3 | 4 | 5 |
| 56. I am finally using precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 57. I have been successful at using precision agriculture and I plan to continue. | 1 | 2 | 3 | 4 | 5 |
| 58. I am satisfied with not using precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 59. I have been thinking that I might want to start using precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 60. I have started using precision agriculture within the last two years. | 1 | 2 | 3 | 4 | 5 |
| 61. I could use precision agriculture, but I don't plan to. | 1 | 2 | 3 | 4 | 5 |
| 62. Recently, I have started to use precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 63. I don't have the time to use precision agriculture right now. | | | | | |
| 64. I don't have the skills to use precision agriculture right now. | 1 | 2 | 3 | 4 | 5 |
| 65. I have started to use precision agriculture, and I plan to continue. | 1 | 2 | 3 | 4 | 5 |
| 66. I have been thinking about whether I will be able to use precision agriculture tools. | 1 | 2 | 3 | 4 | 5 |
| 67. I have set aside some time to start using precision agriculture within the next year. | 1 | 2 | 3 | 4 | 5 |
| 68. I have managed to use precision agriculture for the last two years. | 1 | 2 | 3 | 4 | 5 |
| 69. I have been thinking that I may want to begin to use precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 70. I have lined up with a professional to start using precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 71. I have completed two years of using precision agriculture. | 1 | 2 | 3 | 4 | 5 |
| 72. I know that using precision agriculture is worthwhile, but I don't have time for it in the near future. | 1 | 2 | 3 | 4 | 5 |
| 73. I have been calling other farmers or agricultural professionals to find someone to help me start using precision agriculture within the next year. | 1 | 2 | 3 | 4 | 5 |
| 74. I think using precision agriculture is good, but I can't figure it into my schedule right now. | 1 | 2 | 3 | 4 | 5 |
| 75. I really think I should work on getting started with using precision agriculture within the next two years. | 1 | 2 | 3 | 4 | 5 |
| 76. I am preparing to start using precision agriculture within the next year. | 1 | 2 | 3 | 4 | 5 |
| 77. I am aware of the importance of using precision agriculture, but I can't do it right now. | 1 | 2 | 3 | 4 | 5 |

**Please continue to page 4.**

**Section 8: For each statement below, please rate *HOW IMPORTANT* the statement is to your decision to use or not to use precision agriculture tools. If you feel a statement does not apply to you, rate it as Not At All Important. You are not ranking your agreement with a statement, but rather how important the statement is in your decision to use precision agriculture tools. Circle one for each statement.**

| Not at all important | Not important | Neither | Important | Very Important |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| | Precision agriculture tools… | Not at all important | | | | Very Important |
|---|---|---|---|---|---|---|
| 78. | …reduce costs. | 1 | 2 | 3 | 4 | 5 |
| 79. | …increase yields. | 1 | 2 | 3 | 4 | 5 |
| 80. | …increase profits. | 1 | 2 | 3 | 4 | 5 |
| 81. | …reduce chemical inputs. | 1 | 2 | 3 | 4 | 5 |
| 82. | …allow for efficiently targeting nutrients. | 1 | 2 | 3 | 4 | 5 |
| 83. | …provide environmental information. | 1 | 2 | 3 | 4 | 5 |
| 84. | …allow me to acquire and analyze field data. | 1 | 2 | 3 | 4 | 5 |
| 85. | …increase my cropland's value. | 1 | 2 | 3 | 4 | 5 |
| 86. | …increase the amount of cropland I can manage. | 1 | 2 | 3 | 4 | 5 |
| 87. | …increase attention to management. | 1 | 2 | 3 | 4 | 5 |
| 88. | …decrease financial risks. | 1 | 2 | 3 | 4 | 5 |
| 89. | …collect information on the variability within fields. | 1 | 2 | 3 | 4 | 5 |
| 90. | …reduce farm labor. | 1 | 2 | 3 | 4 | 5 |
| 91. | …manage labor resources. | 1 | 2 | 3 | 4 | 5 |
| 92. | …allow me to create my own field experiments. | 1 | 2 | 3 | 4 | 5 |
| 93. | …are expensive. | 1 | 2 | 3 | 4 | 5 |
| 94. | …require me to have skills that I do not have. | 1 | 2 | 3 | 4 | 5 |
| 95. | …require me to get training in order to use these tools. | 1 | 2 | 3 | 4 | 5 |
| 96. | …provide data that are difficult to interpret. | 1 | 2 | 3 | 4 | 5 |
| 97. | …are dependent on machinery. | 1 | 2 | 3 | 4 | 5 |
| 98. | …require a large farm to be cost effective. | 1 | 2 | 3 | 4 | 5 |
| 99. | …require me to find support sources for advice. | 1 | 2 | 3 | 4 | 5 |
| 100. | …require an understanding of agronomy. | 1 | 2 | 3 | 4 | 5 |
| 101. | …are time consuming. | 1 | 2 | 3 | 4 | 5 |
| 102. | …are difficult to integrate into traditional farming. | 1 | 2 | 3 | 4 | 5 |
| 103. | …are difficult to use. | 1 | 2 | 3 | 4 | 5 |
| 104. | …are difficult to keep abreast of new and upgrade technologies. | 1 | 2 | 3 | 4 | 5 |
| 105. | …are expensive to keep up-to-date with the newest technologies. | 1 | 2 | 3 | 4 | 5 |

**Section 9: General Questions**

106. Are you employed outside the farm? Please check one. ____ No ____ Yes

107. What is the highest level of education that you have **completed**? Please check one.

___ Some high school ___ High school or GED __ Trade school
___ Some college ___ 4-year college __ Graduate/professional school

108. Including sales of all crops, livestock, poultry, and miscellaneous agricultural products (including the landlord's share) and government agricultural payments, which category represents the total gross value of sales from your operation last year (2004)? Please check one.

___ Less than $10,000 ___ $10,000 to $24,999 __ $25,000 to $49,999
___ $50,000 to $99,999 ___ $100,000 to $249,999 __ More than $250,000