IMPROVING PRODUCTION AGRICULTURE EFFICIENCIES AND PROFITABILITY THROUGH THE DEVELOPMENT OF NEW PLANTING TECHNOLOGIES

by

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ABSTRACT

With a large portion of U.S. farm production expenditures related to the cost of fertilizer, seed, and chemicals, producers within the Corn Belt region are looking for new methods and/or planting processes that would deliver higher levels of production efficiencies and lower operating costs. Specifically within the planting operation, Corn Belt producers are faced with the challenge to better manage the higher cost of crop inputs in order to sustain profitability. The primary objective of this thesis is to examine new planting technologies that would better manage planting applications while directly lowering related input costs. Another objective is to understand through regression analysis how various planting variables affect yield potential. Results from the regression analysis illustrate how the various planting variables affect yield and show the importance of “real-time” planter management, advancements possible only with the new planter technology.

Customer surveys and several on-site customer visits were conducted throughout the Corn Belt to better understand the actual needs of producers for new planting technologies. Throughout the customer visits, specific questions about the producers’ planting operation were asked to find new ways for precision technology to help increase overall productivity and ultimately profitability. Producer comments and feedback were analyzed through Quality Functional Deployment (QFD) practices and aligned into product development programs. The products developed from the customer research will help producers in the Corn Belt to reduce corn production inefficiencies and, potentially, increase profit margins, assuming profit levels remain steady and/or increase in lieu of reduced input costs.

Farm level net present value (NPV) analyses of new planting technologies were performed. Corresponding yield data from efficiencies gained in seed corn placement and control during “real-time” planting applications were integrated into the NPV analyses along with the precision technology costs. The NPV results were positive.

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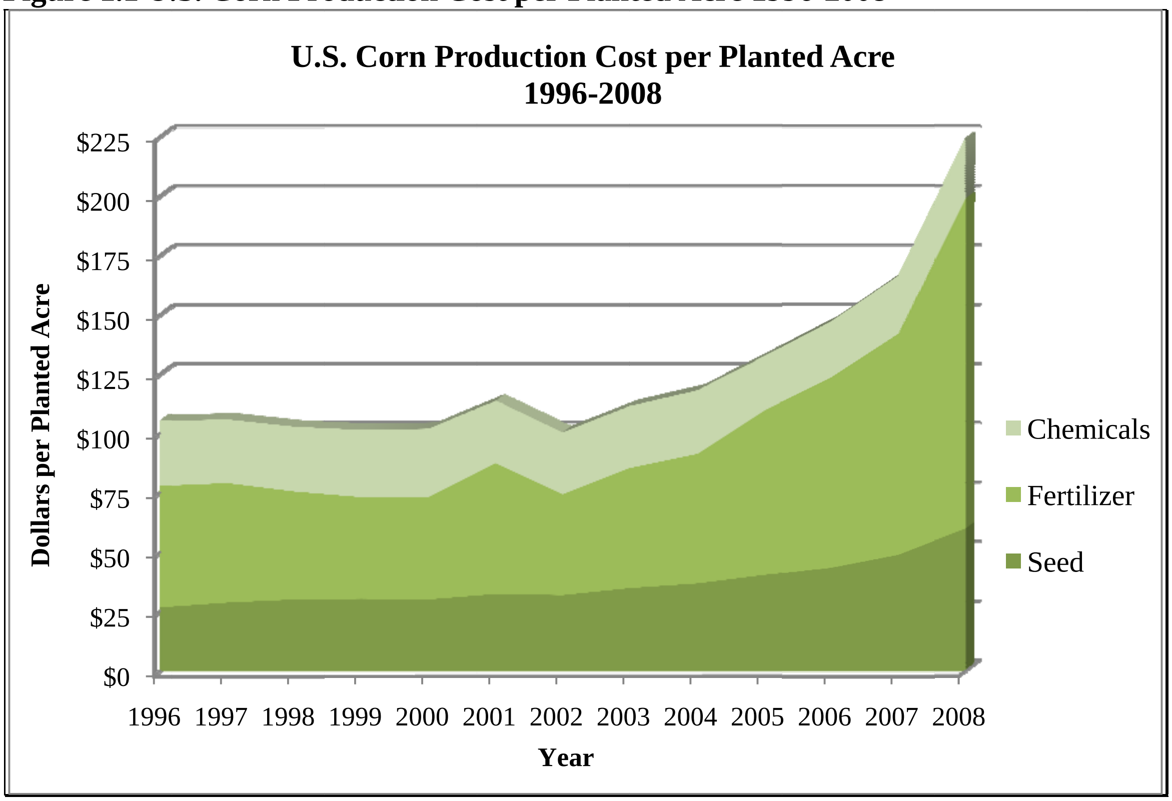
CHAPTER 1: INTRODUCTION

1.1 Problem Statement

The cost to plant corn has increased over the past 13 years, but mostly since 2004 (Figure 1.1). The rising cost of fertilizer and seed corn increases the importance of improving the efficiency of using those two inputs in particular.

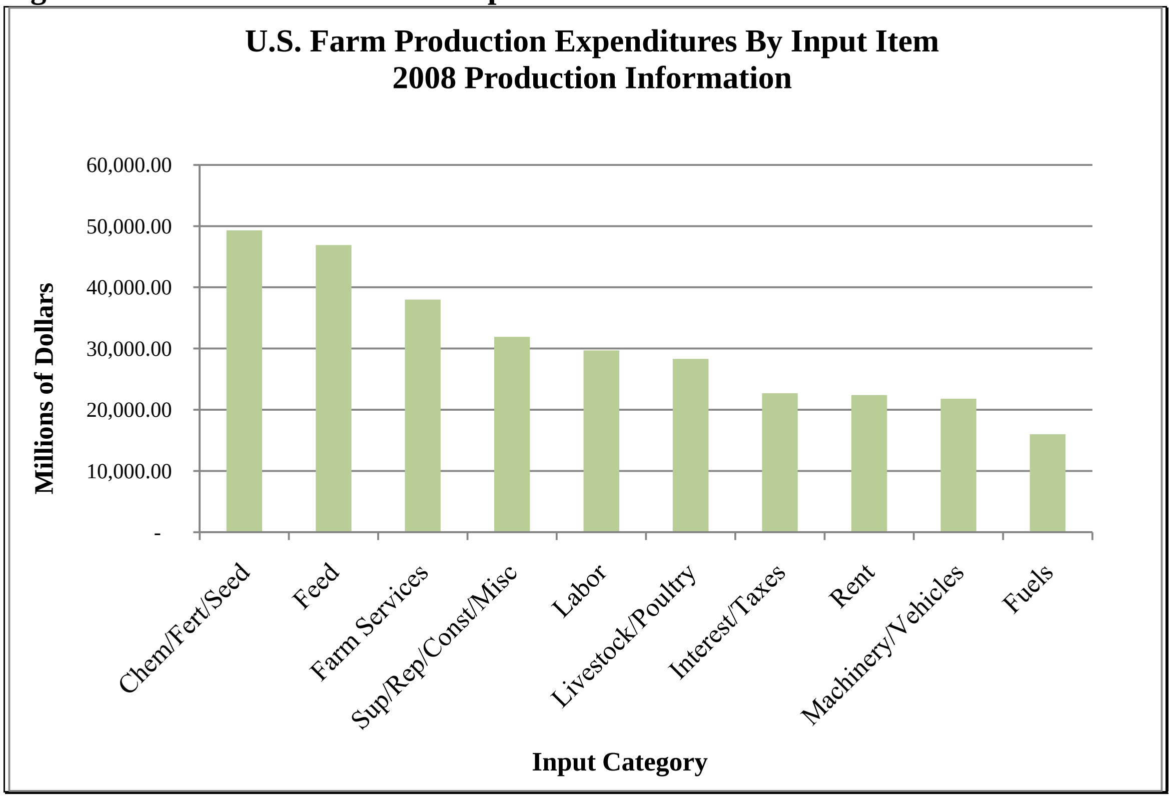
Figure 1.1 U.S. Corn Production Cost per Planted Acre 1996-2008



Source: USDA ERS, Farm and Rural Business Branch

As can be seen in Figure 1.2, the input category seed, fertilizers, and chemicals ranks number one in cost. In 2008, roughly $49.3 million U.S. dollars were spent on seed, fertilizer and chemicals throughout all U.S. production agriculture.

Figure 1.2 U.S. Farm Production Expenditures



Source: USDA NASS- August 2009

With the price of those planting inputs rising, cost minimization (or producing output at the lowest possible cost) must be achieved in order to create higher profit potential (Baye, 2006). From this we will evaluate use of precision planting technologies and their direct impact on planting input costs and the potential to increase efficiency of input use. This study focuses specifically on reducing seed input costs with the development of new seed monitoring and control technologies for planting applications.

1.2 Objectives

The objective of this study is to examine the economic feasibility of investing in precision planting technologies for corn production. The precision planting technologies examined focus on the development of a) new enhanced monitoring system, b) planting "as-applied" mapping, and c) individual planter row-unit controls. All of the precision planting systems are analyzed to understand the relative impact they have on planting efficiencies gained and potential profitability.

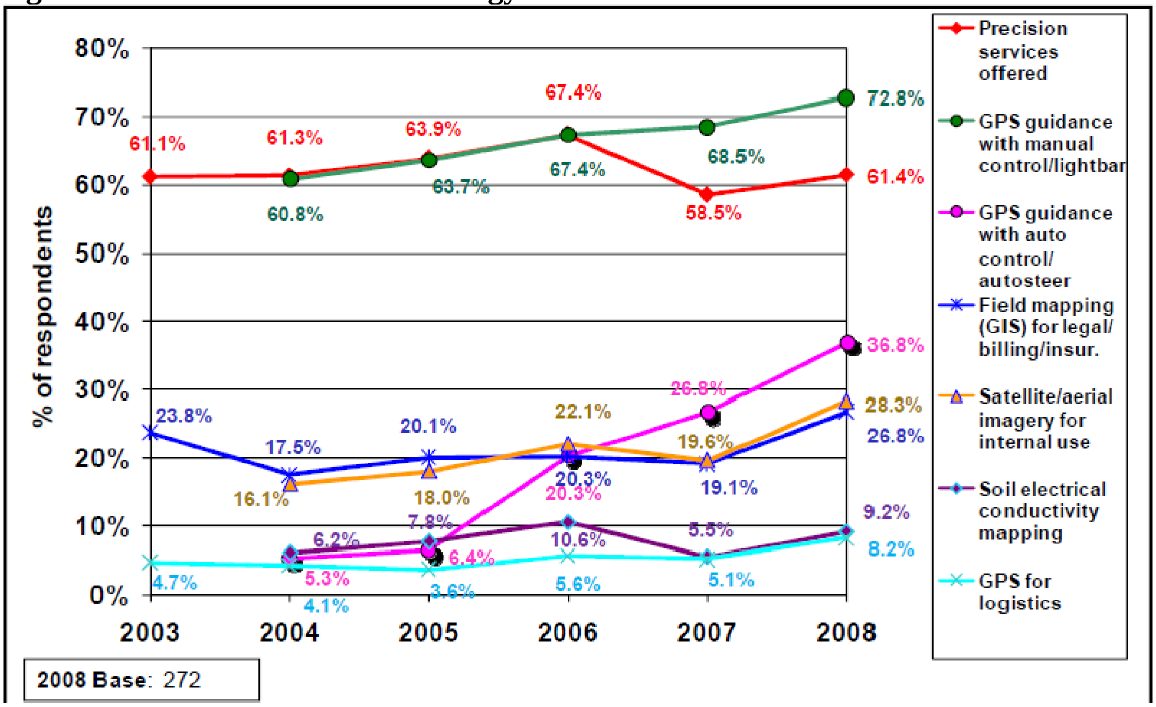
CHAPTER 2: LITERATURE REVIEW

Precision farming technologies are being explored and adopted within many different areas of production agriculture. Precision agriculture promises to make better farm management decisions and identify specific areas of improvement in crop production. According to Bullock and Bullock (2000), "While information provided by agronomic data about the relationship between crop yields, managed inputs, soil characteristics and weather variables has always been valuable…the advent of precision agriculture technology has made information provided by agronomic experiments now even more valuable than ever". Agronomic experiments conducted on plant physiology and nutrient utilization can now be used more effectively and applied directly to crop production. Furthermore, Bullock and Bullock (2000) suggests the need for more long-term, multi-regional agronomic experiments. "For before scholarly experts can provide separate management recommendations for many very small areas of farmers' fields, they will need to know much more than they currently do about the relationships between crop yields, input application rates, soil characteristics, and weather variables".

The need to match the agronomic practices or resource applications with soil and crop requirements as they vary throughout space and time within a given field can be considered as one form of precision agriculture. While some of the technological tools associated with precision agriculture may be obvious, the "fundamental concept will stand or fall on the basis of scientific experimentation and assessment", according to Whelan (2000). Therefore is it crucial to scientifically assess and experiment with site-specific crop management practices “given the large temporal variation evident in crop yield relative to the scale of a single field”. Furthermore, Whelan suggests that the optimal risk aversion strategy when addressing yield potential within a given field is uniform management practices as promised with precision agriculture.

New technologies are being used more frequently within crop production operations within the Midwest. According to the 2008 Precision Agricultural Services Dealership Survey, which was sponsored by *Crop Life* Magazine and the Center for Food and Agricultural Business Department of Agricultural Economics Purdue University, Akridge and Whipker (2008), “83 percent of the respondents used precision technologies in some way in their dealership”. In terms of the types of precision technologies being used within the production agricultural operations, there is a wide variety. From the 2008 Precision Agricultural Services Dealership Survey, “some uses of precision technology have increased while other have remained fairly stable”, as seen in Figure 2.1.

Figure 2.1 Use of Precision Technology over Time



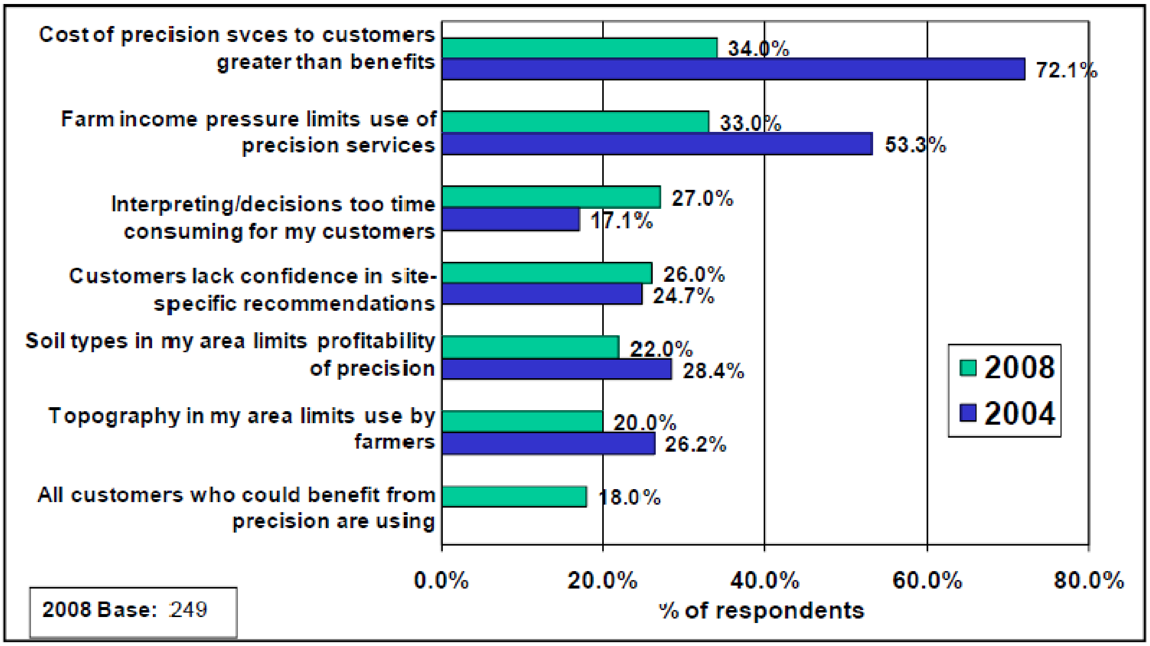
Source: 2008 Precision Agricultural Services Dealership Survey, which was sponsored by Crop Life Magazine and Center for Food and Agricultural Business Department of Agricultural Economics Purdue University.

Over time, there have been a lot of changes in terms of precision farming technologies. With this in mind, the 2008 Precision Agricultural Services Dealership Survey asked specific questions in regards to the “Precision 2.0”, or how much participants plan to spend on precision technology in 2008 along with the potential barriers that would deter higher adoption rates of precision technology. From the survey, there was some concern over making technology “more user-friendly to support more on-farm growth in use of precision services”. Along with that, several other comments were noted from the survey, such as:

- "Farmer purchase and use of GPS technology for planting/harvesting purposes is where this area is going", producer from Alabama.
- "I see the future becoming more technical from the office's standpoint. Everything being implemented on the computer in the office before being put into the machine", producer from Illinois.

Producer assessment of the economics of precision farming technology has changed rapidly in recent years. As can be seen in figure 2.2, 72 percent of respondents in 2004 said that the costs outweighed the benefits, but by 2008 only 34 percent said that the costs outweighed the benefits—less than half the percentage of 2004. Also, as indicated from the survey, "respondents were most uncertain about the profitability of variable seeding with GPS, with 21 percent indicating they didn't know whether or not they were covering costs", but such results were based on few survey responses in relation to this topic.

Figure 2.2 Percentage of Respondents who Agree/Strongly Agree with Customer Issues that Create Barrier to Expansion/Growth in Precision Agriculture 2004 vs. 2008



Source: 2008 Precision Agricultural Services Dealership Survey, which was sponsored by Crop Life Magazine and Center for Food and Agricultural Business Department of Agricultural Economics Purdue University.

Combining agronomic and economic research principles and applying to precision agriculture can be beneficial in making profitable farm management decisions. Still, Fiez, Miller, and Pan (1994), writes that one needs to be cautious using university recommendations based on "yield potential" or other data from site-specific resources. In a 1989-1991 field study of the application of nitrogen fertilizer on soft winter wheat in Washington, Fiez, Miller and Pan (1994) showed results that implied that it would not have been profitable for a producer to use variable fertilizer application rates if the producer used university-recommended rates. However, within this same field trial, it may have been profitable if the producer had enough information (site-specific) to determine the economically optimal variable fertilizer application rates. This result reinforces the importance of having site-specific information (i.e. soil characteristics, yield data, etc) in order for producers to "customize" their farm management practices with the assistance of precision farming technologies.

In planting applications, Bullock *et al.* (1998), used a large set of data from a study conducted on farm fields through the Midwestern Corn Belt between 1987 and 1996 to estimate the economic value of variable rate seeding as compared to uniform rate seeding and concluded that "profitable implementation of variable rate seeding of corn would require detailed information regarding site characteristics, production inputs, and stochastic factors".

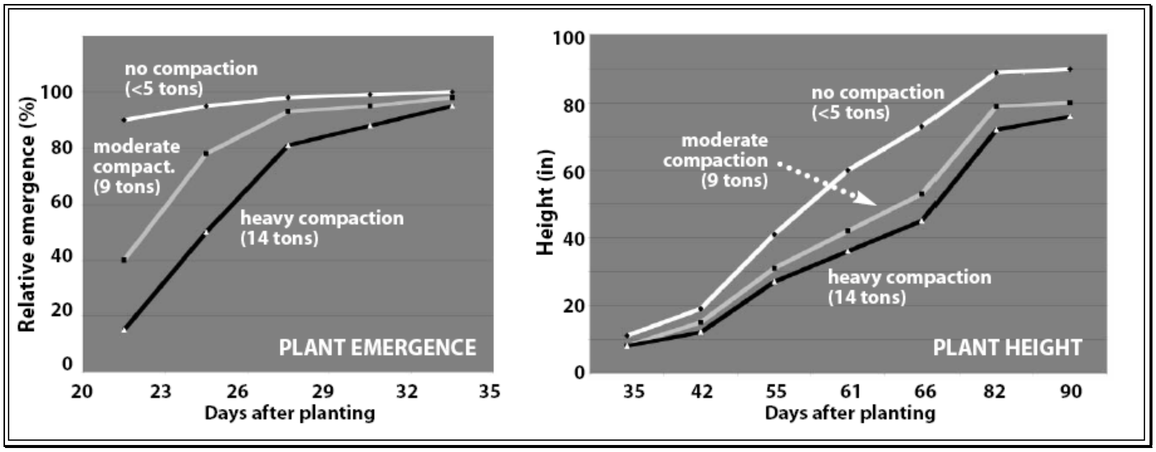
Having site-specific characteristics during the planting process could allow producers to thoroughly model the planting process in "real-time" applications and make necessary adjustments. Specifically, data on seed spacing, singulation, row-unit down force, row unit dynamics, and variable-rate planting could enable the producer to make better seed management decisions (variable-rate drive) along with fine tuning the planter operation for optimal planting results. However, would such improvements, i.e. improving seed spacing, etc., make a difference in corn yield? Furthermore, what quantifies "seed spacing" information within a corn planting application?

Seed spacing, properly known as plant spacing variability (PSV), "can be measured as the standard deviation (SD) of consecutive plant-to-plant spacing within rows", according to Nielsen (2004). Data collected by Nielsen (2004) from a large-scale field study at a single location in northwest Indiana in 2004 indicate "that uneven plant spacing within rows decreases corn yield at a rate of approximately 2.2 bushels per acre for every inch increase in standard deviation of plant-to-plant spacing". La Barge and Thomison's (2002) study of 354 corn stand observations collected in Ohio and Indiana from 1987 to 1996 found that "84 percent of the fields had a standard deviation in plant-to-plant spacing of more than 4 inches, which translated into potential yield losses of 5 to 12.5 bushels per acre. Furthermore, the research conducted in Indiana indicated that a one-inch increase in standard deviation of plant spacing resulted in yield losses up to 2.5 bushel per acre.

Liu *et al.* (2004) observed contrary results from several PSV experiments conducted at two locations in south-central Ontario during 2000 and 2001. By planting Roundup Ready® corn mixed with increasing proportions of conventional corn seeds and removing the conventional corn using glyphosate before the three-leaf stage, they obtained six plant spacing treatments with two different standard deviations of plant spacing: 6.7 and 16.2 cm. Using standard deviation as the measure of PSV, the effects of plant spacing variability on corn growth and grain yield were evaluated. From the results of this study, averaged across all locations, "grain yield was not significantly affected by plant spacing variability". Studies by Nielsen (2004) and studies by Liu *et al* (2004) produce contradictory results, however, other variables such as moisture nutrient availability and light availability may have contributed to the mixed results.

Another site-specific planting variable to consider when applying precision agriculture practices for better, more uniform management is soil compaction. According to Wolkowski and Lowery (2008), "soil compaction is the physical consolidation of the soil by an applied force that destroys structure, reduces porosity, limits water and air infiltration, increases resistance to root penetration, and often results in reduced crop yield". Even though many producers in the Corn Belt know the yield reduction impact of soil compaction, it is often underestimated. Soil compaction can have a detrimental effect on both corn emergence and plant height, as seen in Figure 2.3.

Figure 2.3 Effect of Compaction on Corn Emergence and Plant Height on a Silt loam Soil at Lancaster, Wisconsin.



Source: University of Wisconsin-Extension 2008. Richard Wolkowski (Senior Scientist) and Birl Lowery (Professor of Soil Science), College of Agricultural and Life Sciences, University of Wisconsin-Madison.

From Figure 2.3, we see that corn plant emergence was severely retarded by soil compaction. Specifically 22 days after planting, almost 90 percent of the corn seed emerged in soils with no compaction as compared to 14 percent emergence for soils with heavy compaction. Along with emergence, there is the impact of soil compaction on plant height. Within 61 days after planting, plants emerging from soils with no compaction had an average height of 60 inches as compared to 35 inches for plants that emerged from seeds planted in heavily compacted soils. Another issue is delayed emergence and the role of seed-to-soil contact in delayed emergence. Nafziger, Carter, and Graham (1991), conducted field experiments at the University of Illinois and the University of Wisconsin and concluded that “emergence delays of about 10 days scattered throughout the field reduced yield 6 to 9 percent compared to full stands of normal emergence. Emergence delays of about 21 days reduced yield 10 to 22 percent compared to a full stand of normal emergence, depending on the proportion of delayed emergers to normal emergers”. Their results demonstrate how timely, uniform plant emergence can impact corn yield potential. It can be argued that having uniform seed depth and good seed-to-soil contact will allow for optimal plant emergence conditions to exist, increasing the likelihood of good plant emergence and improved corn yields.

CHAPTER 3: CONCEPTUAL MODEL

3.1 Introduction

Within the realm of making financial and economic decisions that would impact the overall bottom line for any business, several steps could be taken. Along with using financial and economic concepts to make decisions, statistical tools can be used to analyze data to provide management information. This study utilizes profit maximization concepts, regression techniques, and net present value analysis to determine the value to producers of precision planting technology.

3.2 Profit Maximization

Profits may be increased at the margin through achieving greater operating efficiencies and controlling production costs. Specifically, using new planting technologies that enable a producer to understand areas of an operation in which greater efficiencies could be gained could be used to reduce costs or increase production or both. Any of the three would result in higher profits. There are several planting inputs—seed, fertilizer, equipment costs, fuel, labor, and repair and maintenance—that directly impact the producer's bottom line. However, this study focuses specifically on reducing seed input costs with the development of new seed monitoring and control technologies for planting applications.

3.3 Conceptual Model

During the planting operation, there are several variables that could impact the amount of seed used and yield potential. The amount of seed used can be reduced by minimizing the amount of planting overlap at point rows or when crossing headland rows. New advancements in individual row-unit control systems to reduce overlap of seeding could allow for greater cost savings and profit gain for the producer. And in the planting operation, variables that could impact overall yield potential are as follows:

- Seed Spacing
- Seed Singulation
- Seed Depth Consistency
- Excessive Row-unit Down Force (soil sidewall compaction)
- Seed Hybrids
- Overplanting (excessive seeding)

These variables are believed to impact overall corn yield as described in the following general functional form:

(3.1) $\textit{Yield}_{(Bushels)} = f(\textit{Seed spacing}_{(Percent)}, \textit{Seed singulation}_{(Percent)}, \textit{Seed depth consistency}_{(Coefficient\ of\ variation)}, \textit{Excessive row unit down force}_{(Pounds)}, \textit{Seed hybrids}_{(Brand)}, \textit{Overplanting}_{(Percent)}).$

The planting variables that may impact corn yield are described in detail below.

Seed Spacing- The consistency of seed placement during planting process may potentially affect yield. In other words, seeds that are placed equal distances from each other within a seed furrow would theoretically have optimal agronomic growing conditions, i.e., moisture and light availability. From this, it is hypothesized that the seed spacing coefficient would have a positive sign. As the percent good seed spacing increases, the impact on overall corn yield will be positive.

Seed Singulation- Seed singulation refers to corn rows that have no seeds planted in “multiples” or “skips”. Both seed “multiples” and “skips” are related to overall planter meter performance. It is hypothesized as seed singulation increases (percent seed singulation within the planter meter), corn yield will be impacted in a positive manner.

Seed depth consistency- During the planting application, row unit operating depths could change depending on the planter’s relative speed, amount of row-unit down force (lbs/N needed to overcome opposing vertical forces in the ground). As a result, standard deviation and coefficient of variation measures derived from the actual and target seed depths will be analyzed for relative seed depth consistency. In this application, it is hypothesized as the seed depth coefficient of variation increases, seed depth becomes less consistent. From an agronomic perspective, as the seed depth becomes less variable or more uniform, this provides optimal seed emergence potential, thus positively impacting corn yield.

Excessive row-unit down force- During the corn planting process, planter row units can be adjusted to apply different amounts of vertical force (down force measured in pounds/Newton- lb/N) in relation to the horizontal axis (planting field). But throughout a given planting application, the amount of row-unit down force needed for proper planting can vary somewhat depending on the soil type (sandy, loamy, or clay), moisture levels, etc. From this, it is hypothesized that as excessive row-unit down force increases (soil compaction) sidewall compaction increases, which inhibits plant root penetration and plant growth potential. Known as excessive row-unit down force, it is calculated by subtracting the needed down force from the applied down force measurement. The needed down force is measured at the row-unit gauge wheel as the amount of force to obtain 100 percent gauge wheel contact. With current down force systems available, one constant setting is applied. That creates the potential for applying too much row-unit down force (excessive down force). As a result, excessive row-unit down force will have a negative impact on corn yield.

Seed hybrids- Depending on the seed corn hybrid at hand, the genetic composition of the seed could impact corn yield. From this, dummy variables supporting the various seed hybrid field observations will be included into the regression model for analysis. It is hypothesized that seed hybrid will have either a negative or positive effect on yield performance.

Overplanting- Traditional planting practices in the Corn Belt typically require some allotment of planting overlap at point rows or headlands in order to have sufficient planting coverage in the field. However, this results in seed to be double planted in those regions of the field. The result is higher than optimal planting populations (in many cases twice the target planting population). It is hypothesized that overplanting in such regions of the field cause increased plant competition for limited agronomic support factors, i.e., nutrients, light utilization and water. Thus, it is hypothesized that overplanting will impact corn yield, negatively.

All of the noted planting variables above provide an opportunity to create a product/solution that can enable the corn producer to actively monitor such variables during the planting operation and take the appropriate measures. However, consideration of stochastic variables that the manager has little to no control over impacting corn yield complicates the management practices and resulting yield. These stochastic variables include:

- Pest and disease pressures
- Climatic pressures, i.e., drought, flooding, etc.
- Soil cationation, exchange capacities (CEC) for nutrient retaining properties

3.4 Field Data Regression

As noted, there are several planting variables that could impact overall corn yield. With these variables in mind, it is desired to understand the overall relationship between controllable planting variables--seed spacing, seed singulation, seed depth consistency, and excessive row-unit down force (independent variables) and corn yield (dependent variable). Regression analysis will be used to estimate the hypothesized production relationships. Regression analysis is a statistical technique that attempts to “explain” movements in one variable, the dependent variable, as a function of movement in a set of other variables, called the independent (or explanatory) variables, through the quantification of a single equation,” according to Studemund (2006).

3.5 Net Present Value

Net present value (NPV) calculations for the new planting technologies are used to calculate the economic feasibility of investing in new technology. NPV calculates the present value of the streams of returns gained from investment in the new precision planting technologies minus the stream of costs of investing in and operating precision planting technologies. Current agricultural machinery loan interest rates are used for discounting the cash flows of the investment to the present.

Returns from the investment in addition to costs are required for the analysis. Field data acquired from the 2009 planting and harvesting season and information from previous university studies are utilized to simulate planting efficiencies and yield gains from the new precision planting technologies. The yield information is used to calculate the additional revenue gained from investing in the technology. The cost of investing in and operating the new precision planting technologies are subtracted from the additional return to arrive at a net present value and internal rate of return.

CHAPTER 4: DATA AND METHODOLOGY

4.1 Objectives

The objective of this study is to examine the economic feasibility of investing in certain aspects of precision planting technologies for planting corn, specifically a) new, enhanced monitoring system, b) planting “as-applied” mapping, and c) planter individual row-unit controls. All of the precision planting systems are analyzed to understand the impact each has on improved planting efficiencies and increased yields and net returns. Understanding how efficiencies may be improved with the development of new precision planting technologies are studied with on-site farm visits and surveys administered through a John Deere customer-based support group. Furthermore, prior university field-trial studies and regression analysis of field data are utilized to understand how planting improvements may positively impact yield. Potential gains in yield through use of new precision planting technologies will be translated directly into potential revenue gain, and then, compared to the additional cost of investing in precision planting technologies using a net present value (NPV) analysis framework.

4.2 Data Gathering

Understanding the areas of the planting operation where greater efficiencies could be gained and addressed through the development of new precision planting technologies required a) visiting a number of farms across the Corn Belt that produce corn, b) conducting market research through customer surveys and mediated customer focus groups, and c) conducting field-plot research to examine how the previously discussed planting variables impact corn yield.

4.3 Producer On-Site Visits

Visits were made to 25 of the most progressive producers within the Corn Belt and surrounding regions (Table 4.1). The objective of those visits was to understand how to improve planter monitoring technology in order to assist producers in making better management decisions while data is retrieved during planting.

Table 4.1 States Visited for Gathering Customer Requirements Supporting the Enhanced Monitor Project

State	Amount of On-Site Producer Visits
Illinois	5 Producers
Iowa	8 Producers
Mississippi	3 Producers
Minnesota	2 Producers
North Dakota	5 Producers
Tennessee	2 Producers

Corn growers were asked how the planting operation could be improved in order to gain greater efficiencies. After collecting the producer comments and feedback from the on-site visits, the information was integrated into a quality functional deployment (QFD) matrix to properly align customer needs to precision planting technology product development (Appendix A). According to Crow (2001), "QFD is a powerful tool to plan products, define their requirements or technical characteristics and plan subsequent details to achieve the product. QFD provides a mechanism to assure that appropriate new product technology to support customer needs is investigated".

4.4 Market Research

Two customer surveys were administered to better understand the need for individual-row-control technology on planters. One survey was developed and administered through a customer focus group conducted in the spring of 2009 to ask specific questions about the value and product needs supporting individual row control. The questions for that survey were constructed from current market intelligence and specific design inquires from engineering. It was administered to 12 top producers within the Corn Belt. The information received was analyzed and consolidated to provide guidance on the development of a new individual-row control system for corn planters.

The other survey focused on the value and estimated cost savings of an individual row control system. Specifically, a question asked the corn producers to estimate the actual seed corn savings with individual row control. That survey was administered in January 2010 to an exclusive group of 1,115 US and Canadian John Deere customers, better known as the John Deere Panel. Those participating in this survey are often involved with discussion forums and surveys relating to a variety of agricultural topics. Results from this internally administered survey provide an estimate of the potential seed input savings found with individual row control systems (Appendix C).

4.5 Field Plot Research

Field data to support the regression analysis was obtained in collaboration with Robert Wieland, from Laura, IL, a top corn producer. Specifically, planting and yield data were obtained from the 2009 planting/harvest season via data processing monitors located on Wieland's John Deere 1770NT 24 Row 30" Planter and John Deere 9870 STS combine. Specific planting and yield data were downloaded from the implement data processors and viewed through John Deere APEX® integrated management software. Then, the field data were converted into Microsoft Excel format and used in the previously discussed regression model. In total, over 23 individual field data plots were analyzed for a total of 1,503 acres observed. The data observed and used in the regression model is shown in Table 4.2.

Table 4.2 Field Data Variables for Regression Model

Avg. Yield (bu/ac)	**Seed Hybrid (brand of seed corn)**	**Excessive Row-unit Down Force (lbs/N)**
Seed Depth Consistency (coefficient of variation)	**Percent Seed Singulation (percent seed singulated)**	**Percent Good Seed Spacing (percent within two inch standard deviation)**

4.6 Precision Technology Costs

Costs of investing and operating the new technology are needed for the NPV analysis. Internal John Deere pricing information acquired from the Deere Pricing Department in Lenexa, KS is used.

4.7 Producer Operational Costs and Average Yield

To conduct the NPV analysis, average corn yield (bushel/acre), seed corn cost (dollar/bag), and average corn acres are needed to estimate the additional returns of the new planting technologies. Corn production data from the 2009 growing season in the Corn Belt was obtained from USDA NASS for the NPV analyses. The opportunity cost of capital is used in determining a discount rate for the NPV calculation. The current agriculture equipment prime rate plus 1.5 discount points is used for the discount rate. This was obtained from the John Deere Credit division.

4.8 NPV Methods

The NPV analyses will be based on calculations in the cash flow streams (Figure 4.1).

Figure 4.1 NPV Calculation

$$NPV = -C_0 + \left[SV_n \times (1+i)^{-k} \right] + \left(\sum_{k=1}^{N} (R) \times (1-i)^{-k} \right) - \left(\sum_{k=1}^{N} (VC_k) \times (1+i)^{-k} \right)$$

Where:

NPV	=	net present value of all returns or savings associated with the new technology for n years
i	=	discount rate
k	=	1 to 4 years
C_o	=	investment cost for the new technology
SV_n	=	salvage value of the equipment at the end of the last year (n_{th}) year of use
R	=	returns from new technology in the k_{th} year
VC_k	=	variable costs of new technology in the k_{th} year

The returns (R) are calculated for an enhanced monitoring system and an individual row-unit control system as described in equations 4.2 and 4.3.

(4.2) R_1 = additional yield × acres × price ($/bu.)

(4.3) R_2 = reduction in seed used (%) × original seed cost ($/acre × acres)

The discount rate used in the analysis is 4.75 percent, the initial investments costs are $13,108 for the enhanced monitor system and $11,688 for the individual row-unit controls system. The length of life of the new technology is assumed to be 4 years (based on expected payoff time) and there is zero salvage value. Variable costs for operating and maintaining the new technology are assumed to be zero.

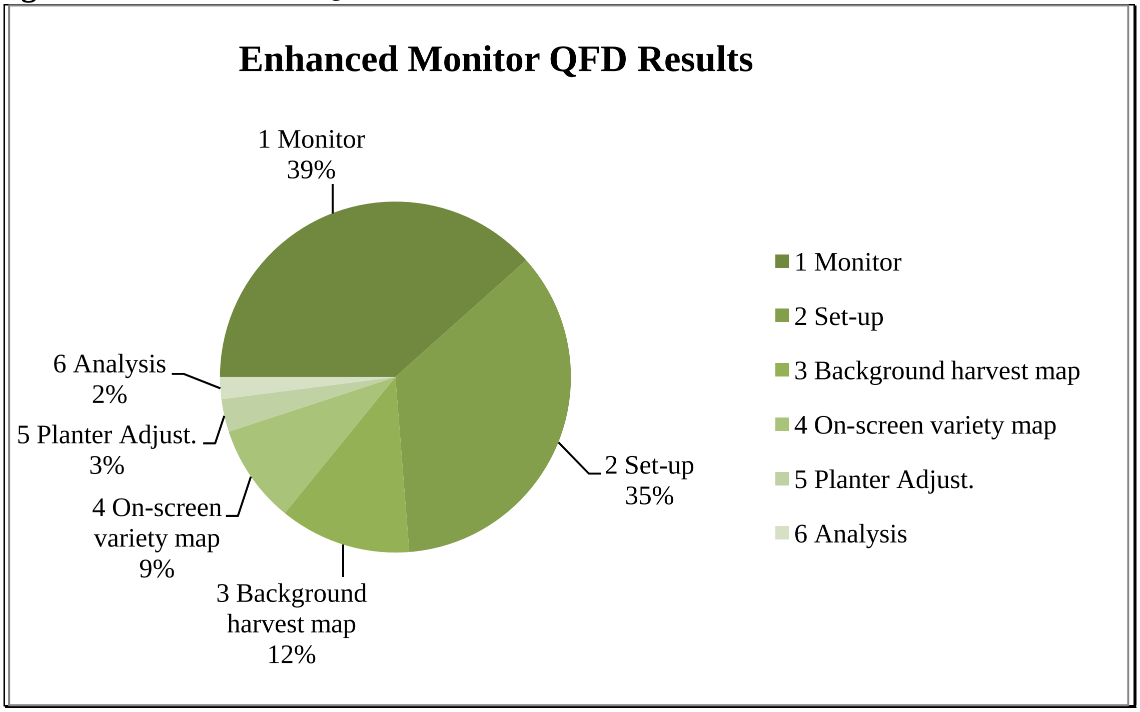
CHAPTER 5: RESULTS

5.1 Summarized QFD from Producer On-Site Visits

Visits with the 25 progressive producers produced several ideas of how new technologies could improve corn planting efficiencies. The ideas ranged from planting documentation to new advancements in monitoring technology.

After summarizing the customer feedback through a QFD analysis, it was clear that planter monitoring was one portion of the planting operation where improvements could be made (Figure 5.1). More specifically, a new planter monitor to assist producers during the planting process using “real time” data transmitted to the tractor cab is desired.

Figure 5.1 Summarized QFD Results from On-Site Producer Visits



5.2 Summarized QFD Results for Planter Monitoring

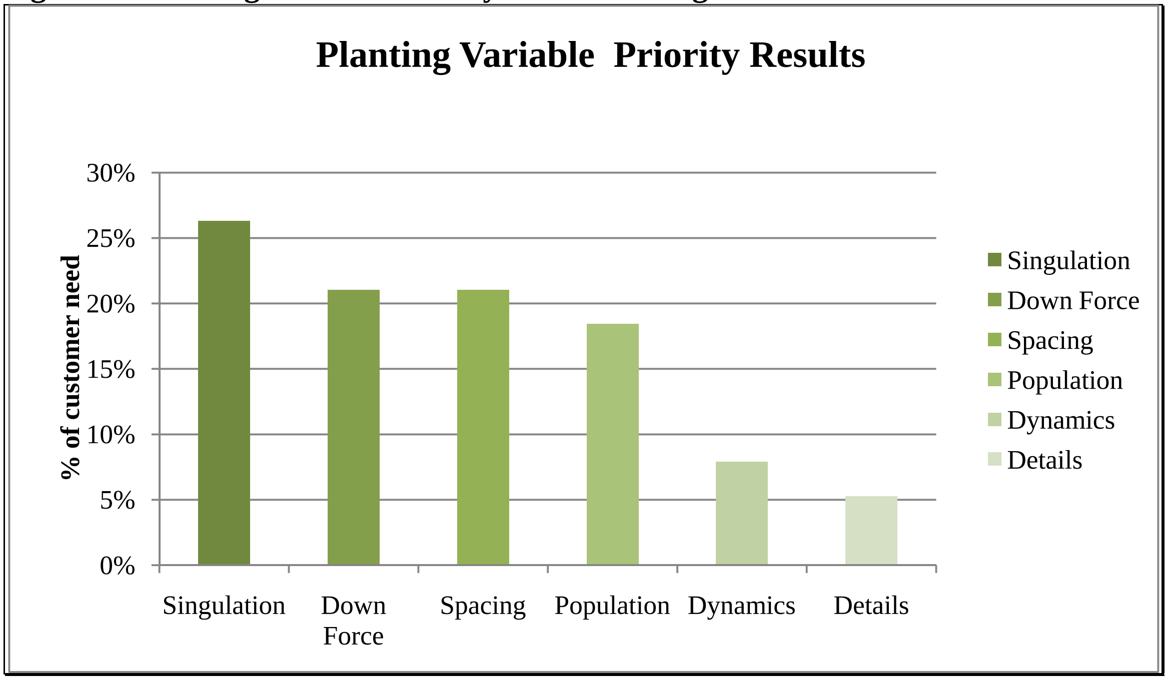
Several questions were asked during the customer visits about how the planter monitoring functions could be improved. When customer responses were evaluated, it became apparent that advancements in planter monitoring needed to include the ability to measure and monitor planting variables that would impact overall yield potential. The planting variables are reported in Table 5.1.

Table 5.1 Planting Variables for Monitoring

Seed Singulation	Seed Spacing	Population
Row-unit Down Force	Row-unit Dynamics	Row-unit Details (Summary)

The planting variables in Table 5.1 were prioritized by the producers and summarized to determine the variable that had the highest priority. These results are summarized in Figure 5.2.

Figure 5.2 Planting Variable Priority for Monitoring



After determining the need to develop a new planter monitoring product that would effectively provide “real-time” data on the planting variables, an approval for capital expenditure (AFE) from Deere and Company was obtained in order to develop a new planter monitoring system through a dedicated product development program (PDP). Engineering and marketing efforts are currently in place to develop a new enhanced monitoring system for planting applications.

5.3 Enhanced Planter Monitor Development

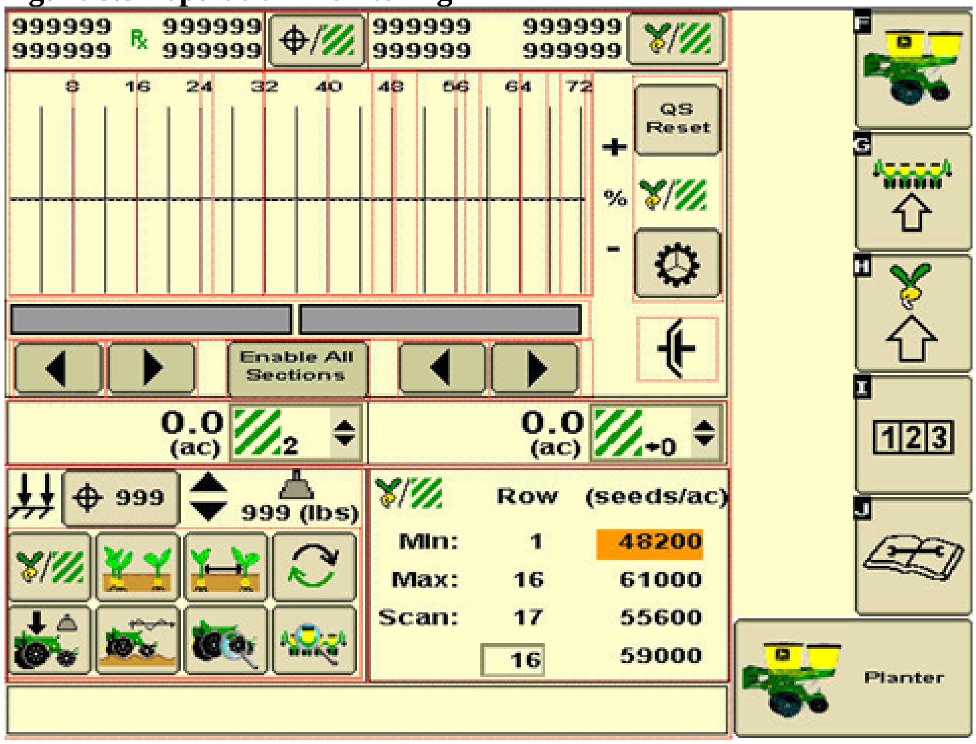
An enhanced planter monitor will enable the producer to monitor all of the planting variables listed in Table 5.1 and enable producers to make the necessary planter adjustments to gain higher levels of planting efficiencies. An overview of the enhanced monitor is presented in the following section.

5.3.1 Population Monitoring

The ability to actively monitor the planting population (seeds per acre) allows producers to ensure that the correct planting population levels are maintained throughout the field. Depending on soil conditions, producers could actively use the population monitoring feature to make appropriate seed rate adjustments (through use of variable-rate drive) in manual or prescription-based roles in order to apply the right seed population based on the soil conditions (water and nutrient retaining properties) in hopes of improving yield and reducing costs due to excess seed corn planting.

Preliminary design work has been accomplished. Figure 5.3 shows the new monitor user face that producers within the Corn Belt and other regions could use to actively change to planting populations and monitor the overall planter performance. The layout and configuration of the monitor face was based on customer comments during the design phase.

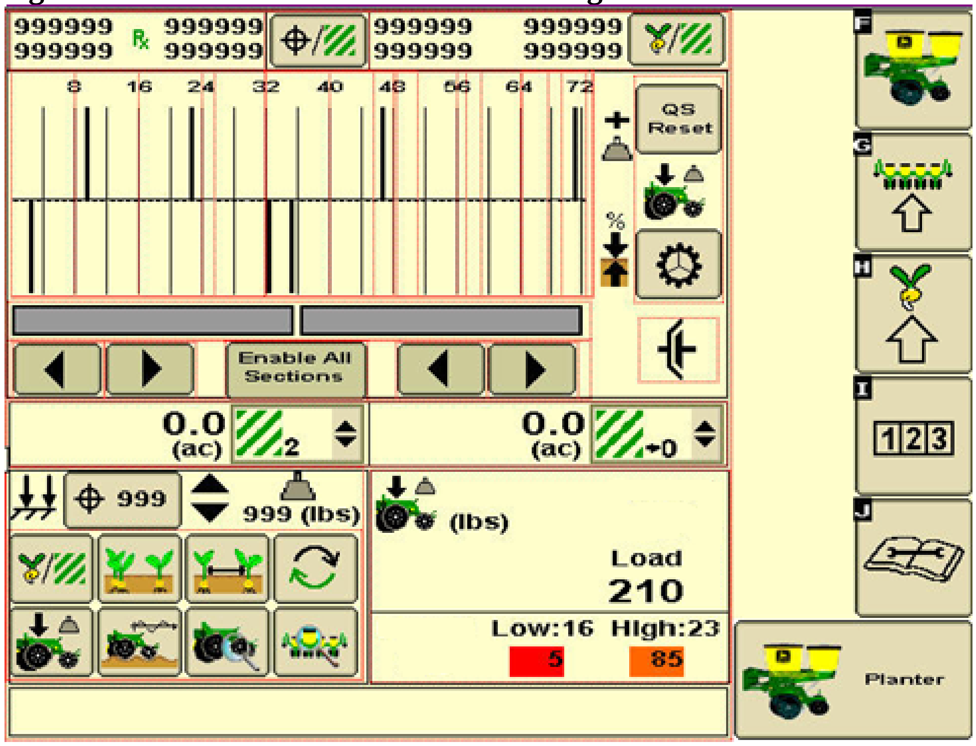
Figure 5.3 Population Monitoring



5.3.2 Row-unit Down Force Monitoring

Approximately 21 percent of the customers surveyed during the on-site visits ranked row- unit down force as reported by the planter monitor as the highest priority. To support this request, development of an average row-unit down force measurement, known as “load” in Figure 5.4, was initiated. The row-unit load data point provides the producer with information on the average down force being applied on the row-units during the planting operation.

Figure 5.4 Row-unit Down Force Monitoring

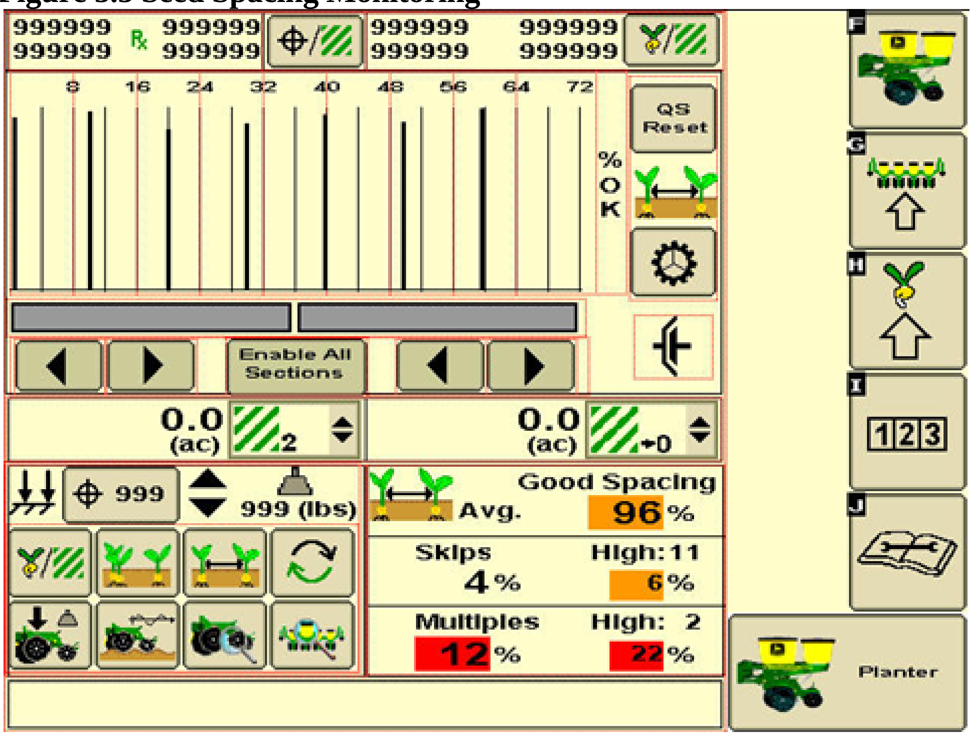


5.3.3 Seed Spacing Monitoring

Having “good seed spacing” equates to having seeds planted equal distance to each other within the furrow. Furthermore, in order to understand how to quantitatively measure seed spacing, planter spacing deviations from the target seed placement point (seed-to-seed) are calculated and evaluated. Seeds that are placed within a two inches of the target seed placement are categorized as being placed properly by the planter, or exhibiting good seed spacing.

Approximately 20 percent of the customers that responded ranked the ability to actively monitor seed spacing as the highest priority. Advancements in the enhanced monitor allow producers to actively monitor average seed spacing while planting. Also this feature allows for the producer to make necessary adjustments to the planter or other planting variables if the desired seed spacing metric does not meet the desired criteria (Figure 5.5).

Figure 5.5 Seed Spacing Monitoring

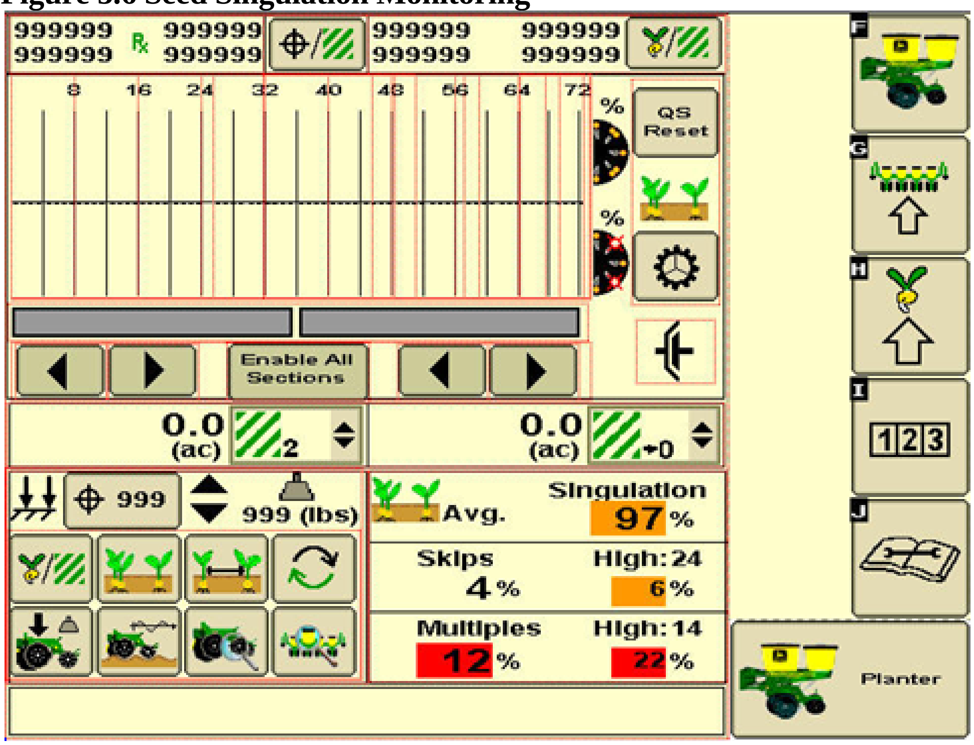


5.3.4 Seed Singulation Monitoring

The planter meter assembly's prime function is to singulate the seed corn entering the meter. A flat seed disk and double eliminator are used to effectively drop a seed down the seed tube within the row-unit shank for placement within the field furrow. By effectively singulating seed within the meter assembly, the release of more than one seed from the meter into the seed tube is mitigated.

Approximately 26 percent of the customers that responded indicated that the ability to actively monitor seed singulation was the most important planting variable. As a result, a design to provide a user interface that shows real-time seed singulation data from the planter was created (Figure 5.6).

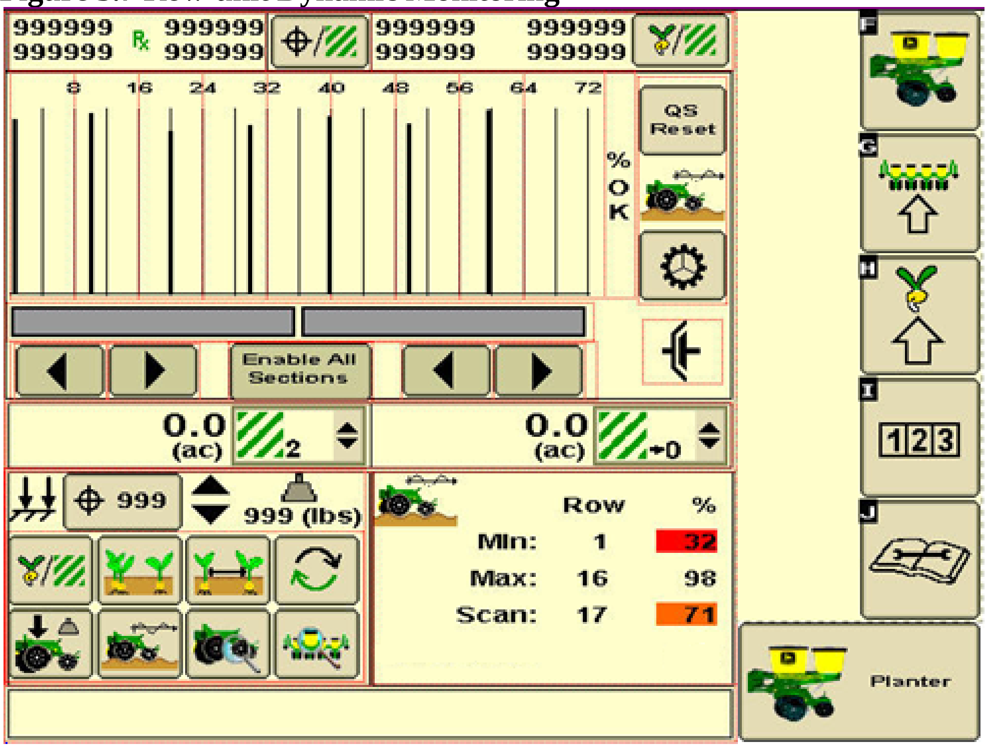
Figure 5.6 Seed Singulation Monitoring



5.3.5 Row-unit Dynamics Monitoring

The ability to measure the relative variation in row-unit vertical motion was discussed with producers during the on-site visits, too. Such information may assist producers to find the optimal planting speed. Of the customers polled during the on-site visits, about 8 percent indicated that row-unit dynamic data was the most important planting variable to be monitored. A planter monitor user face was designed that enables producers to actively monitor row-unit dynamic data across the planter (Figure 5.7). This information will allow the operator to make the necessary adjustments to ensure a smooth, functioning row unit that operates with consistent seed singulation and spacing.

Figure 5.7 Row-unit Dynamic Monitoring



5.4 Individual Row-unit Control Development

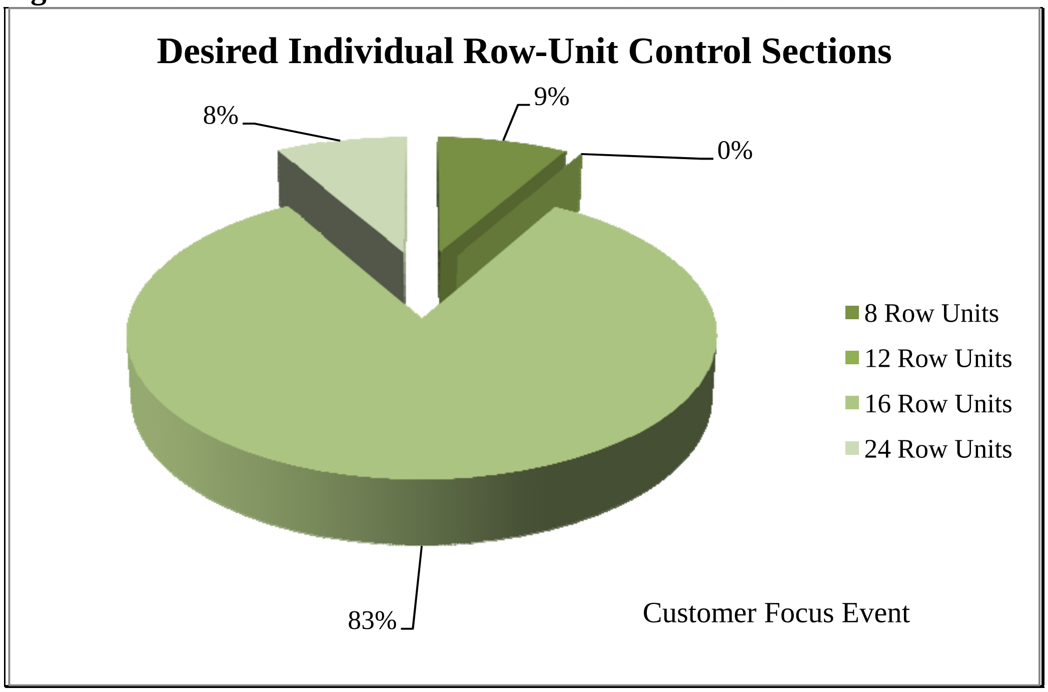
Customer focus group events at the John Deere Proving Grounds in Coal Valley, IL were conducted to discuss development of an individual row-unit control system. John Deere field reports and other market intelligence indicate that producers in the Corn Belt are looking for a means to reduce the rising seed input costs (Figure 1.1). This requires the need to a) understand the market demand for an individual row-unit control, b) develop an exclusive row-unit control system for John Deere planters, and c) price the new product by estimating value-added of the technology.

Several design and functionality questions were presented at the customer reviews held in the spring of 2009 (Appendix B). The questions were asked to top producers within the Corn Belt, primarily in the states of Illinois and Iowa. Key features and performance items were documented from responses to the survey on the development of the individual row-unit control for John Deere planters.

5.5 Individual Row-unit Control Customer Specifications

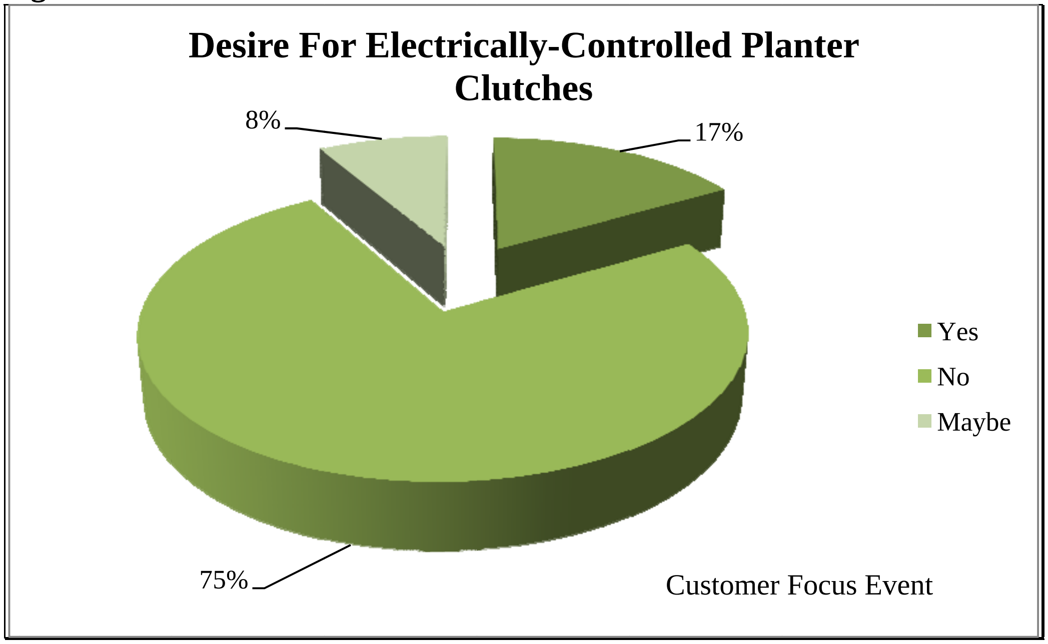
Many producers throughout the Corn Belt have a planter equipped with row units ranging from 6 to 36 row units. Planter size varies depending on the scale of the producer's operation. The amount of individual row units desired to be controlled automatically through guidance systems and mapped field boundaries needed to be documented. The number of row units that could be controlled using the Deere-exclusive Swath Control Pro™ and GreenStar™ 2 Displays was needed for the development of the individual row control system. About 84 percent of the producers that responded to the survey indicated that 16 individual row units were desired (Figure 5.8).

Figure 5.8 Desired Individual Row Units for Automatic Control



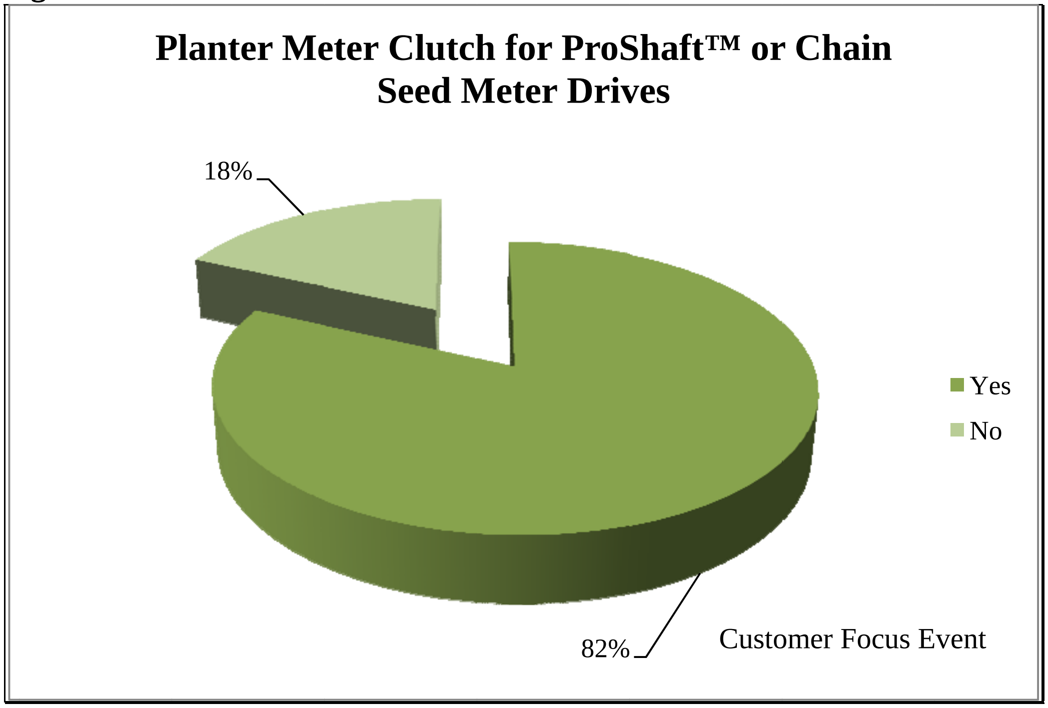
Mechanical design structure was another issue posed in the customer survey. Specifically, would it be optimal to have an individual row-unit control system that was controlled electrically or pneumatically? Furthermore, would the clutches required to engage and disengage the planter meter on the row unit need to be electrically or pneumatically controlled? As reported in Figure 5.9, 75 percent of the producers did not oppose an electrically controlled individual row-unit meter clutch.

Figure 5.9 Choice of Electric or Pneumatic Control for Row Unit Meter Clutch



Lastly, producers were also polled to determine whether efforts were needed to develop two different row-unit planter clutches. Figure 5.9 reports that 82 percent of the producers indicated the need for a planter meter clutch to support planters with chain or Pro-Shaft seed meter drives.

Figure 5.10 Planter Meter Clutch for Chain or Pro-Shaft™ Drives



5.6 Individual Row-unit Control Prototypes

Once the customer information concerning an individual row-unit control system was obtained, work initiated on the design of two planter meter clutches along with the related electrical components. For the individual row-unit control system supporting John Deere planters, the following components have been designed:

- Meter clutch for planters equipped with Pro-Shaft meter drives
- Meter clutch for planters equipped with chain meter drives
- Electronic power modules (EPM) to control the engagement and disengagement of row units when needed.

- New electrical harness architecture with controlled area network (CAN) capabilities.

As shown in Figures 5.10 and 5.11, individual row-unit meter clutches are shown for Pro-Shaft and chain meter drives, respectively.

Figure 5.11 Planter Clutch for Chain Drive

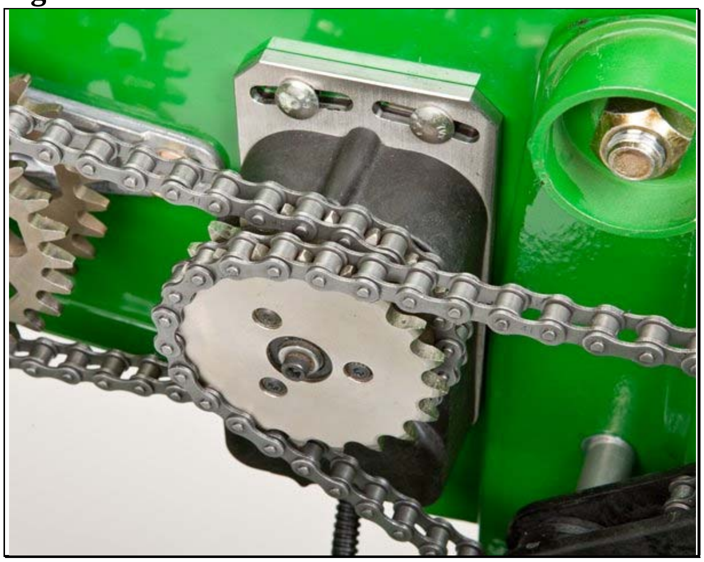


Figure 5.12 Planter Clutch for Pro-Shaft™ Drive

The planter row-unit clutches shown in Figures 5.11 and 5.12 provide the ability to engage and disengage the row-unit meter whenever the Swath Control Pro guidance feature sends a CAN-based communication message to enable such. This allows for control of planting operations at field headlands and point-rows. This eliminates potential yield drag associated with overplanting in these regions of the field. To envision the functionality of the individual row-unit control at point rows and headland, refer to Figure 5.13 below.

Figure 5.13 Individual Row-unit Control Field Results

Source: 2009 Planting Season using John Deere 1770NT 16Row30 with Individual Row Unit Control

5.7 Results of Field Data Regression

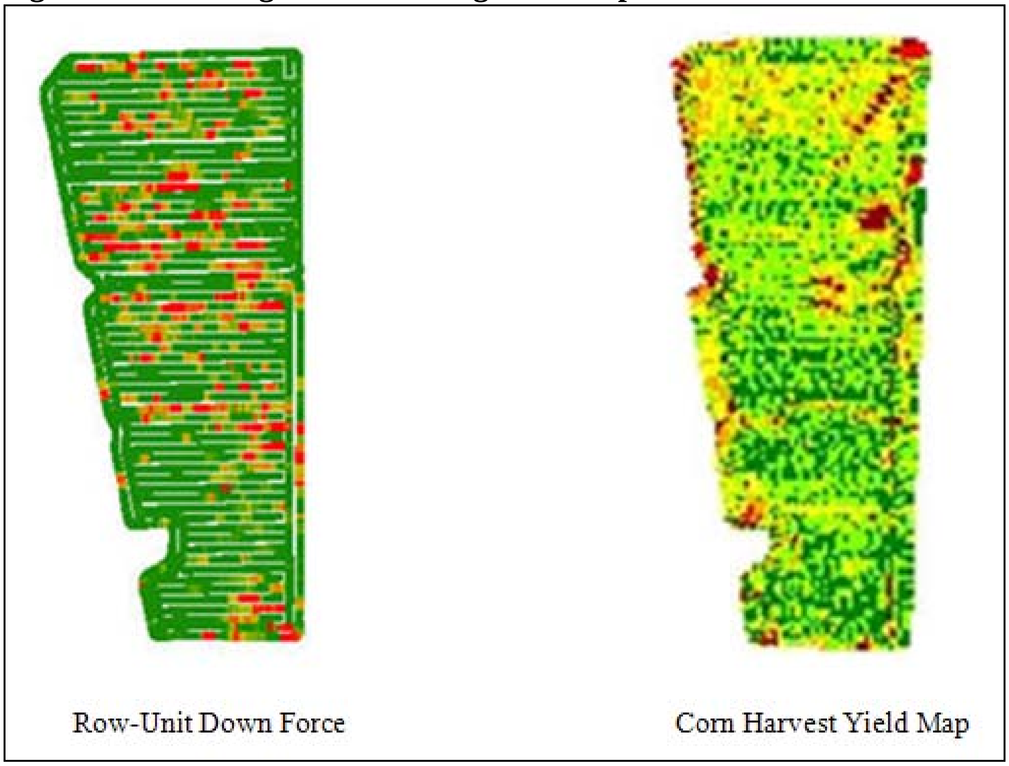
Field data supporting the regression analysis was collected from 23 individual fields observed in Illinois and summarized (Appendix D). Table 5.2 outlines the type of data obtained and compiled.

Table 5.2 Data Fields Collected

Farm	**Field**	**Avg. Yield (bu/ac)**	**Seed Hybrid (brand of seed corn)**
Excessive Row-unit Down Force (lbs)	**Seed Depth Consistency (coefficient of variation)**	**Percent Seed Singulation (percent seed singulated)**	**Percent Good Spacing (percent within two inches of target spacing)**

The data obtained from the 2009 planting and harvest seasons was evaluated using integrated management software in order to create dedicated field maps and compile the data into Excel-formatted spreadsheets. Field maps shown in Figure 5.13 provide an example. These maps show areas of excessive row-unit down force (planting application) and corn yield map (harvest application) for a specific field. By comparing the row-unit down force map (left) and the respective corn yield map (right), a producer can evaluate whether a planting variable (e.g., excessive row-unit down force) could impact corn yield. Even though many variables (such as crop and insect management, weather, and moisture availability) affect yield, comparing maps such as those in Figure 5.13 can be a beneficial crop management practice.

Figure 5.14 Planting and Harvesting Field Maps



A regression analysis was performed using the following linear functional form where corn yield is the dependent variable and seed spacing, seed singulation, seed depth consistency, and excessive row-unit down force are the independent variables (Equation 5.1). Since the aforementioned planting variables are being monitored with the enhanced monitor, a stronger understanding of how each variable impacts yield is needed.

(5.1) $\textit{Yield}_{(Bushels} = f(\textit{ Seed spacing}_{(Percent)}, \textit{Seed singulation}_{(Percent)}, \textit{Seed depth consistency}_{(Coefficient\ of\ variation)}, \textit{Excessive row-unit down force}_{(Pounds),})$.

Table 5.3 Regression Analysis for Enhanced Monitor Planting Variables

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.526811185
R Square	0.277530025
Adjusted R Square	0.116981142
Standard Error	23.03863704
Observations	23

ANOVA

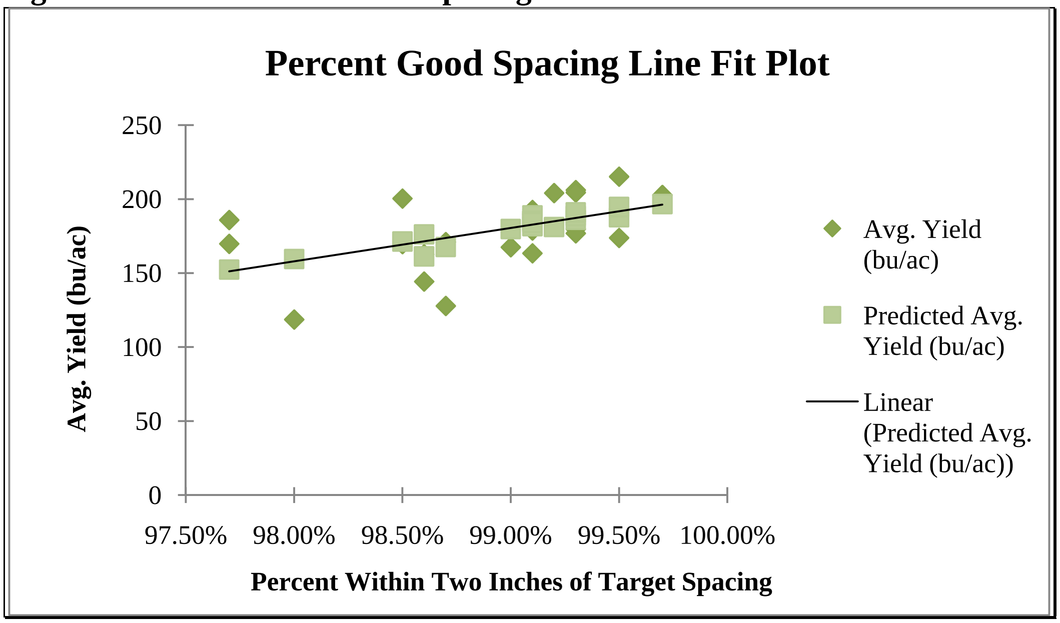
	df	*SS*	*MS*	*F*
Regression	4	3670.086009	917.5215	1.728633
Residual	18	9554.018339	530.7788	
Total	22	13224.10435		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-2295.82664	945.3555487	-2.42853	0.025864
Excessive Down Force (lbs)	-0.501280588	0.795235975	-0.63035	0.536384
Percent Good Spacing (%)	2457.477908	945.5604969	2.598964	0.018139
Percent Singulation (%)	50.41168528	95.71528275	0.526684	0.604844
Seed Depth Coefficient of Variation	-12.60528913	94.98047335	-0.13271	0.895892

The R-squared value in Table 5.3 indicates that 22.8 percent of the variability in corn yield is explained by the independent variables. This indicates that many other independent variables are present that could impact the dependent variable. The results also indicate that the percent good spacing variable is statistically significant. With a t-statistic value of 2.60 this indicates that percent good seed spacing is significant whereas the other independent variables in the model are not. The other independent variables in the model have fairly insignificant t-statistic value (t <2), and therefore, are not statistically significant towards explaining their impact on the dependent variable.

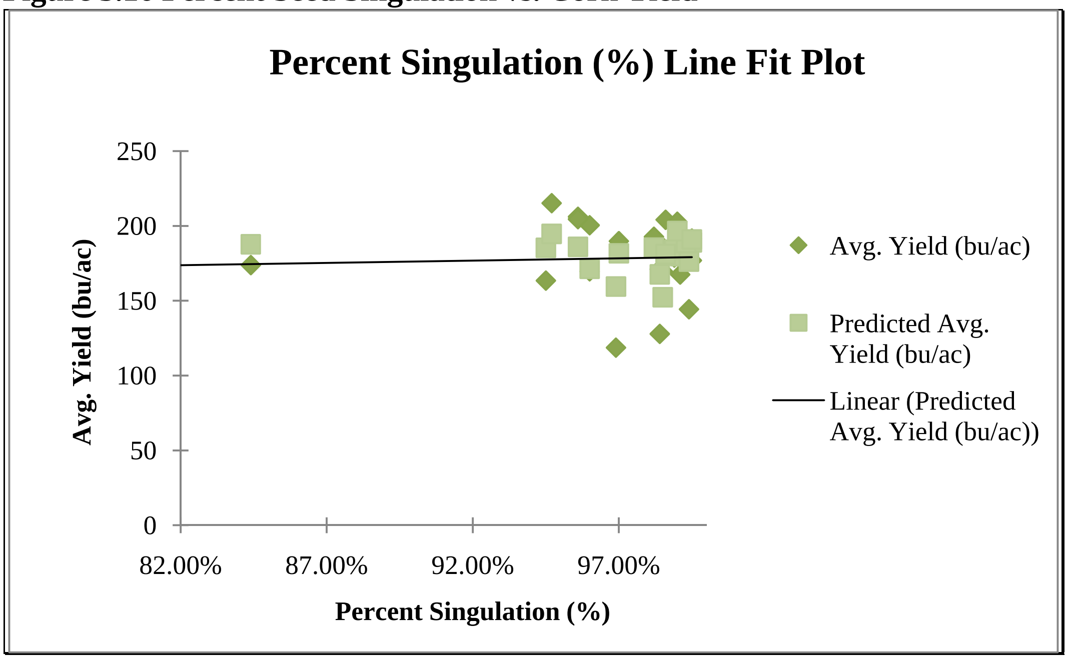
To better understand the relative impact of percent good seed spacing on corn yield, the relationship is graphed in Figure 5.15. The equation in Figure 5.15 indicates that a one percent increase in good seed spacing equates to 22.54 bushel/acre yield gain. In order words, as more seeds are placed within a two inches of the target seed placement (known as good seed spacing) in the seed furrow, the yield increases.

Figure 5.15 Percent Good Seed Spacing vs. Corn Yield



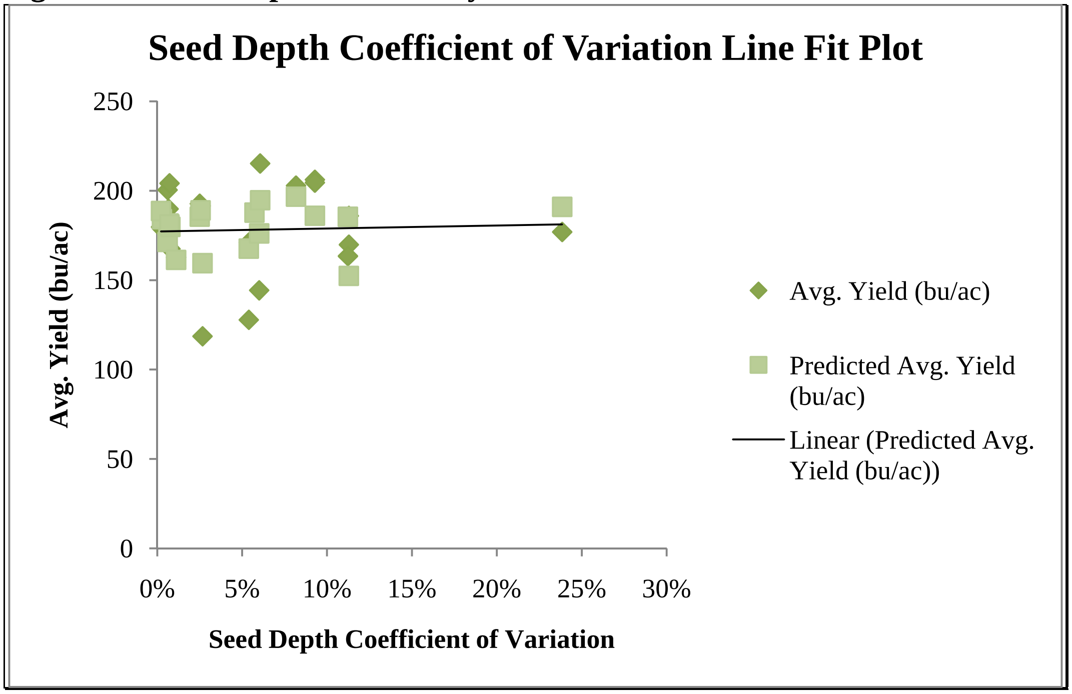
Although not statistically significant, percent seed singulation is positively related to yield and the second most important impact on yield. Results presented in Figure 5.16 show that as the amount of seed properly singulated within the planter meter increases by one percent, yield increases by 0.31 bushel/acre. This conforms to the hypothesis stated within the theory section; as the percent seed singulation increases, corn yield increases.

Figure 5.16 Percent Seed Singulation vs. Corn Yield



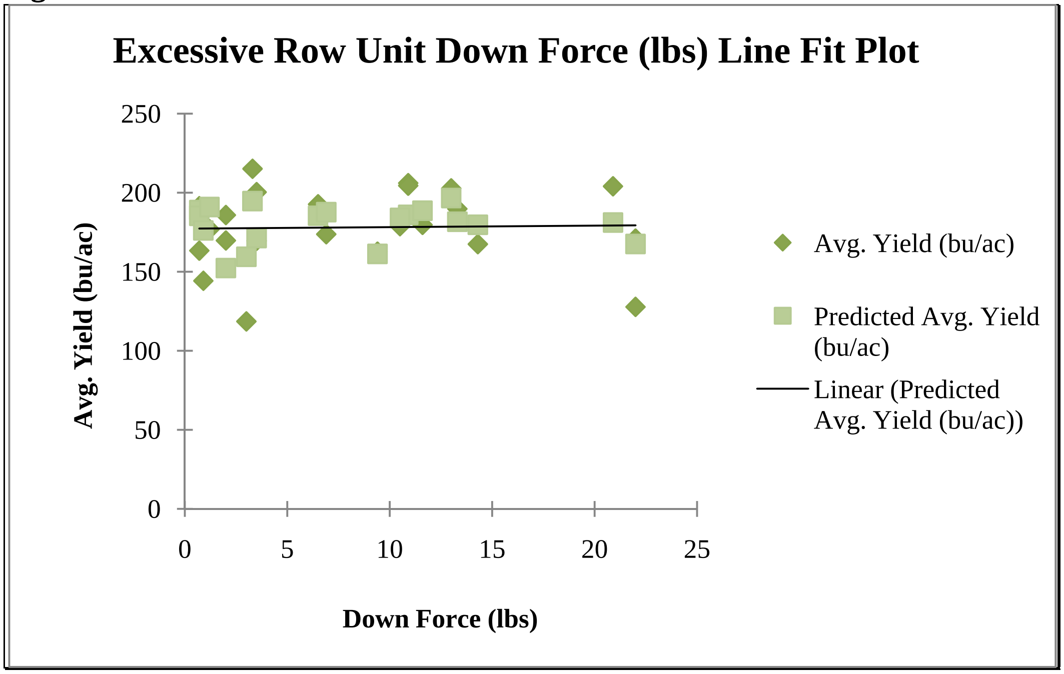
Seed depth consistency, although not statistically significant, was shown to be positively related to yield and the third most important impact of yield. The results reported in Figure 5.17, as the seed depth coefficient of variation increases by one percent, corn yield decreases by 0.12 bushel/acre. This relationship does conform to the hypothesized reaction noted in the theory section.

Figure 5.17 Seed Depth Consistency vs. Corn Yield



Excessive row-unit down force appeared to be the least important variable compared to seed spacing, seed singulation, and seed depth consistency (Figure 5.18). As the amount of excessive row-unit down force increases by one pound, there is a yield increase of 0.09 bushel/acre. This relationship does not conform to the hypothesized relationship stated earlier in the theory section.

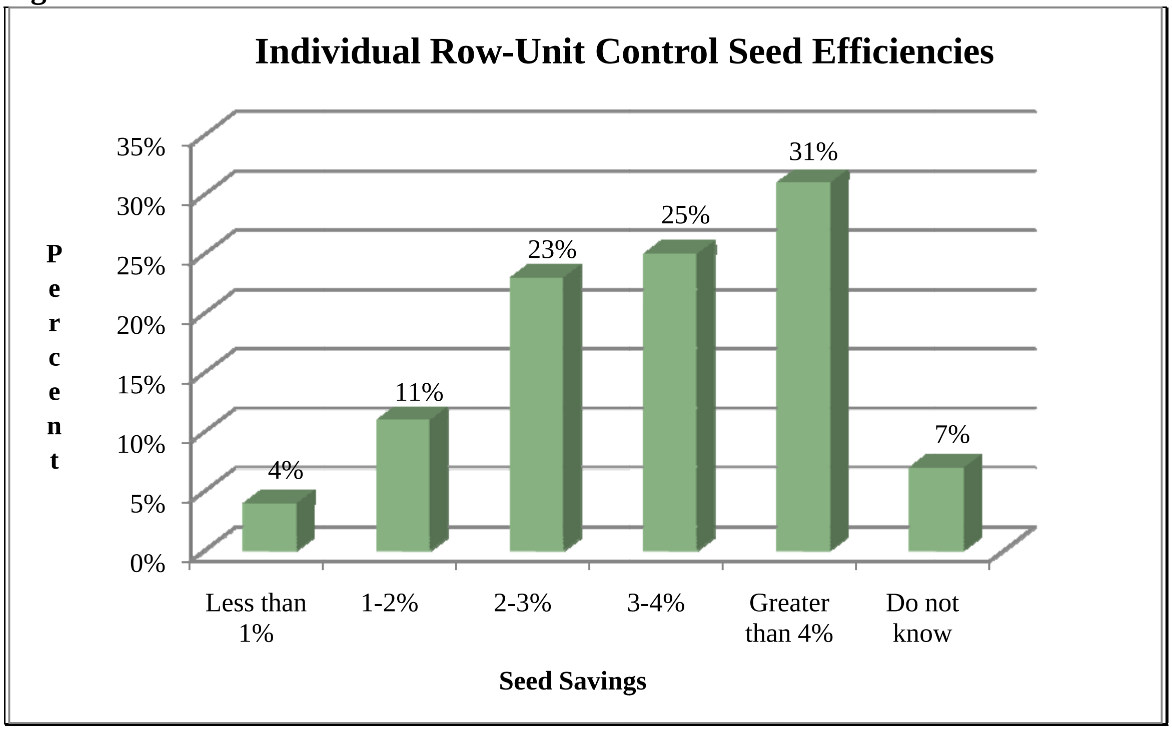
Figure 5.18 Excessive Row-unit Down Force vs. Corn Yield



5.8 John Deere Panel Survey

During the month of January 2010 a survey was conducted with a panel of John Deere and competitor's equipment owners to collect data on the economic impact of individual row-unit control systems. Specifically, this survey targeted customers who operated an individual row-unit control system during the spring 2009 planting season. The survey was sent to 1,115 customers of which 170 returned them. Of those 170 customers who submitted results, 31 percent of them indicated that an individual row-unit control system reduced seed corn input costs over 4 percent (Figure 5.19). Furthermore, another 48 percent of the respondents estimated the seed saving was from two to four percent with the individual row-unit control system to minimize point row and headland planting overlap.

Figure 5.19 John Deere Panel Results-Individual Row-unit Control



5.9 NPV for Enhanced Monitoring

The NPV analysis as described in equations 4.1 to 4.3 was constructed for a typical farm size. The NPV results are reported in Table 5.4.

Table 5.4 NPV Analysis for Enhanced Monitoring

	Opportunity Cost of Capital	4.75%			
Model Inputs		Year One	Year Two	Year Three	Year Four
	Operation Size	418	418	418	418
	Average Yield (bu/ac)	205	205	205	205
	Average Cash Price ($/bu)	$ 3.45	$ 3.45	$ 3.45	$ 3.45
	Seed Corn Cost ($/bag)	$ 250.00	$ 250.00	$ 250.00	$ 250.00
	Seed per Bag	80,000	80,000	80,000	80,000
	Planting Population	34000	34000	34000	34000
	Planter Size (rows)	24	24	24	24
System Cost					
	Enhanced Monitor price per row	$546	$0	$0	$0
	Total Enhanced Monitor System Cost	$13,108	$0	$0	$0
Efficiencies Gained-Enhanced Monitor					
	Seed spacing yield gain (bu/ac)	22.54	22.54	22.54	22.54
	Seed spacing revenue gain ($)	$32,504.93	$ 32,504.93	$ 32,504.93	$ 32,504.93
Cash Flow					
	Enhanced Monitor System	$32,504.93	$ 32,504.93	$ 32,504.93	$ 32,504.93
		($13,108)			
	Net Present Value	$102,825.40			
	Internal Rate of Return	246%			

The average farm size, yield, price and cost per unit of seed input data was obtained by the USDA National Agriculture Statistic Services (NASS) for the 2009 planting season. Cost figures for the enhanced monitoring system were obtained from the John Deere Pricing Department to support the analysis. Opportunity cost of capital of 4.75 percent is equal to the equipment prime rate plus 1.5 discount points. This information was obtained from the John Deere Credit division.

The NPV analysis was constructed for four years of producer use. The cash flows associated with the new enhanced monitoring system were calculated based on the predicted efficiency gained with seed spacing. The field data regression results for seed spacing, the only statistically significant variable found to impact corn yield, was used to calculate the returns to invested with new planting technology. As the percent good seed spacing increased by 1 percent above 97 percent (potentially due to better monitoring of planter performance through the enhanced monitor system), this led to a predicted increase in yield by 22.54 bushels per acre. However, it needs to be considered that many other stochastic variables are present to impact corn yield performance and therefore the 22.54 bushel per acre efficiency gain could be impacted accordingly.

Table 5.5 NPV Analysis Simulation for Enhanced Monitoring

	Opportunity Cost	4.75%			
Model Inputs		Year One	Year Two	Year Three	Year Four
	Operation Size	2200	2200	2200	2200
	Average Yield (bu/ac)	205	205	205	205
	Average Cash Price ($/bu)	$ 3.45	$ 3.45	$ 3.45	$ 3.45
	Seed Corn Cost ($/bag)	$ 250.00	$ 250.00	$ 250.00	$ 250.00
	Seed per Bag	80,000	80,000	80,000	80,000
	Planting Population	34000	34000	34000	34000
	Planter Size (rows)	24	24	24	24
System Cost					
	Enhanced Monitor price per row	$546	$0	$0	$0
	Total Enhanced Monitor System Cost	$13,108	$0	$0	$0
Efficiencies Gained-Enhanced Monitor					
	Seed spacing yield gain (bu/ac)	0.80	0.80	0.80	0.80
	Seed spacing revenue gain ($)	$ 6,051.04	$ 6,051.04	$ 6,051.04	$ 6,051.04
Cash Flow					
	Enhanced Monitor System	$ 6,051.04	$ 6,051.04	$ 6,051.04	$ 6,051.04
		($13,108)			
	Net Present Value	$8,473.89			
	Internal Rate of Return	30%			

To understand the seed spacing efficiency gain needed in order to obtain a more typically internal rate of return (30 percent for the analysis) and operation size to support a 24 row planter, Table 5.5 was created. As seen in Table 5.5, when the internal rate of return was altered to 30 percent, the NPV value remained positive at $8,473.89. And in terms of seed spacing efficiency, a 0.80 bushel per acre gain through the use of the enhanced monitor would have to be obtained in order to achieve the 30 percent internal rate of return.

Investment in an enhanced monitor results in a NPV value of $102,825.40. With a positive NPV value of $102,825.40, it appears that the enhanced monitor system would make economic sense to incorporate into a corn producers operation in order to maximize on efficiency gains during the planting process. The internal rate of return (IRR) for the enhanced monitor is 246 percent. And after simulating IRR to 30 percent, the NPV remained positive at $8,473.89 and required the enhanced monitor to provide a 0.80 bushel per acre yield increase through better planter performance from existing monitoring systems.

5.10 NPV for Individual Row-unit Control

A NPV analysis was also performed for investing in an individual row-unit control system. The NPV results are reported in Table 5.6.

Table 5.6 NPV Analysis for Individual Row-unit Control System

	Opportunity Cost of Capital	4.75%			
Model Inputs		Year One	Year Two	Year Three	Year Four
	Operation Size	418	418	418	418
	Average Yield (bu/ac)	205	205	205	205
	Average Cash Price ($/bu)	$ 3.45	$ 3.45	$ 3.45	$ 3.45
	Seed Corn Cost ($/bag)	$ 250.00	$ 250.00	$ 250.00	$ 250.00
	Seed per Bag	80,000	80,000	80,000	80,000
	Planting Population	34,000	34,000	34,000	34,000
	Planter Size (rows)	24	24	24	24
System Cost					
	Individual Row-unit Control Price Per Row	$487	$0	$0	$0
	Total Individual Row-unit Control System Cost	$11,688	$0	$0	$0
Efficiencies Gained-Individual Row-unit Control					
	Seed savings (% overall)	4%	4%	4%	4%
	Total Seed Savings ($)	$ 9,835.29	$ 9,835.29	$ 9,835.29	$ 9,835.29
	Total Seeding Cost	$ 245882.4	$ 245882.4	$ 245882.4	$ 245882.4
Cash Flow					
	Individual Row-unit Control	$ 9,835.29	$ 9,835.29	$ 9,835.29	$ 9,835.29
		($11,688)			
	Net Present Value	$23,390.95			
	Internal Rate of Return	75%			

The cash flows associated with the individual row-unit control system were calculated based on the results of the John Deere panel survey on the seed input savings that producers feel can be obtained with an individual row-unit control system. Specifically, the efficiencies that could be gained by not overlapping the planting process at field point rows and headlands. An estimated seed input savings of 4 percent was used in the NPV analysis. The highest percentage of responses from the survey was 4 percent or greater (Figure 5.19).

To understand the seed input savings needed in order to obtain a more typically internal rate of return (30 percent for the analysis), Table 5.7 was created. As seen in Table 5.7, when the internal rate of return was altered to 30 percent, the NPV value remained positive at $7,555.87. And in terms of seed input savings, a 0.42 percent reduction in seed inputs through the use of the individual row control system would have to be obtained in order to achieve the 30 percent internal rate of return.

Table 5.7 NPV Analysis Simulation for Individual Row-unit Control System

	Opportunity Cost	4.75%			
Model Inputs		Year One	Year Two	Year Three	Year Four
	Operation Size	2200	2200	2200	2200
	Average Yield (bu/ac)	205	205	205	205
	Average Cash Price ($/bu)	$ 3.45	$ 3.45	$ 3.45	$ 3.45
	Seed Corn Cost ($/bag)	$ 250.00	$ 250.00	$ 250.00	$ 250.00
	Seed per Bag	80,000	80,000	80,000	80,000
	Planting Population	34000	34000	34000	34000
	Planter Size (rows)	24	24	24	24
System Cost					
	Individual Row-Unit Control Price Per Row	$487	$0	$0	$0
	Total Individual Row-Unit Control System Cost	$11,688	$0	$0	$0
Efficiencies Gained-Individual Row-Unit Control					
	Seed savings (% overall)	0.42%	0.42%	0.42%	0.42%
	Total Seed Savings ($)	$ 5,395.52	$ 5,395.52	$ 5,395.52	$ 5,395.52
	Total Seeding Cost	1294117.6	1294117.6	1294117.6	1294117.6
Cash Flow					
	Individual Row-Unit Control	$ 5,395.52	$ 5,395.52	$ 5,395.52	$ 5,395.52
		($11,688)			
	Net Present Value	$7,555.87			
	Internal Rate of Return	30%			

The individual row-unit control system has a NPV value of $23,309.95. With a positive NPV value of $23,309.95, it appears that the new individual row-unit control system would make economic sense to incorporate into a corn producers operation in order to maximize on efficiency gains during the planting process. And furthermore, the internal rate of return (IRR) for the individual row-unit control system is calculated to be 75 percent. And after simulating IRR to 30 percent, the NPV remained positive at $7,555.87 and required the individual row control system to provide a seed input savings of 0.42 percent.

5.11 Summary

Multiple customer surveys and focus groups were administered to understand areas in which new planting technologies could improve production efficiencies. The feedback from the conducted market research developed two new planting technologies; an enhanced planting monitor and individual row-unit control system.

With the development of the enhanced monitor system, field plot research was conducted to understand how various planting variables (seed spacing, seed singulation, excessive row-unit down force, and seed depth consistency) impact corn yield. Data from the field plot research was analyzed through statistical regression techniques to better quantify the relationships between the independent variables (planting variables) and dependent variable (corn yield).

Efficiencies gained from the new enhanced monitor and individual row-unit control systems were quantified and used to conduct the NPV and IRR analysis. The enhanced monitor and individual row-unit control systems yielded positive NPV values, $102,825.40 and $23,309.95 respectively. The respective IRR for the enhanced monitor and individual row-unit control systems were 246 percent and 75 percent. Furthermore, the simulated NPV analyses for a 30 percent IRR indicated positive NPV values of $8,473.89 and $7,555.87 for the enhanced monitor and individual row control systems, respectively.

Although there are other stochastic variables that could impact corn yield potential, an enhanced monitor and individual row-unit control systems are found to create additional net returns by eliminating inefficiencies in the planting process.

CHAPTER 6: CONCLUSION

6.1 Overview

Because of the rising costs of inputs in the Corn Belt and beyond, corn producers are looking for ways to gain efficiencies and minimize total costs to produce higher profit margins. The rising cost of seed inputs (often related with new genetics and hybrids) has placed a need to develop and create new planting technologies and associated products that directly reduce inefficiencies within the planting process. To better understand market conditions and customer needs, several surveys, customer focus groups, and on-site visits were conducted. The survey data were analyzed and quantified using QFD and other methods. This information was used to design new precision planting technologies.

Understanding how such precision planting technologies could improve planting efficiencies was needed in order to evaluate their economic feasibility to the corn producer. Field data from 23 locations was obtained from the spring 2009 planting season and compiled into several categories related to planting variables. The main intent of collecting field data with various planting variables was to understand how each variable impacts corn yield; thus determining how to improve planting management (with the enhanced monitor). The field data was analyzed with statistical regression techniques to specifically determine how each planting variable impacts corn yield. Of the planting variables analyzed for the enhanced monitor, only one variable proved to be statistically significant; percent good seed spacing. The analysis showed improved planting management techniques that increase the amount of equal distance seed spacing provides the greatest opportunity for greater corn yield potential.

Several customer focus groups and producer surveys were used to determine how new individual row-unit control systems could directly impact the amount of seed wasted due to overplanting at field point rows and headlands. Based on survey results, most producers (31 percent of the respondents) indicated that individual row-unit control systems could reduce the amount of wasted seed by approximately 4 percent. By eliminating the potential to overplant fields by 4 percent, this reduces the amount of seed input costs.

Once the efficiency gains were quantified for the enhanced monitor and individual row-unit control systems, the NPV and IRR analysis was conducted. Both the enhanced monitor and individual row-unit control systems yielded positive NPV and IRR values. The NPVs for the enhanced monitor and individual row-unit control system were $102,825.40 and $23,309.95 respectively. The IRRs for the enhanced monitor and individual row-unit control systems were 246 percent and 75 percent, respectively. Furthermore, the simulated NPV analyses for a 30 percent IRR indicated positive NPV values of $8,473.89 and $7,555.87 for the enhanced monitor and individual row control systems, respectively.

6.2 Limitations of the Research

Although the field plot data study involved 23 locations within central Illinois, it would be beneficial to measure the same planting variables within the study across other locations within the Corn Belt. For the 2009 corn growing season in Illinois, there was ample moisture available and the corn crop experienced optimal growing conditions. From this, it would be desirable to know how the respective corn yield would react to poorer growing conditions when planting variables are changed. By obtaining this information from across the Corn Belt, this would develop a more statistically sound representation (larger sample size) on how various planting variables within the thesis work would impact corn yield.

Regression work conducted on other variables impacting corn yield would also provide more information on the expected relationship between all variables analyzed. Such variables are:

- Seed hybrid (Genetically modified or non-genetically modified)
- Fertilizer application program (N, P, K)
- Water management practices (field tile)
- Soil conditions and types (silt loam, loam, clay, etc.)

Understanding the direct relationship of the aforementioned variables towards corn yield would allow for the model to potentially have a higher adjusted R^2 value; thus creating better fit towards explaining the impact of the independent variables towards the dependent variable.

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APPENDIX A: ENHANCED MONITOR QFD RESULTS

Only #1 Priorities for Each Customer	Each cell corresponds to an individual response	Count	AVG	Adj avg
Monitor		7	1.0	0.1
Set-up		8	1.0	0.1
Harvest Map		1	1.0	1.0
Variety Map		1	1.0	1.0
Planter Adjustment		1	1.0	1.0
APEX		1	1.0	1.0

Only #1&2 Priorities for Each Customer	Each cell corresponds to an individual response	Count	AVG	Adj avg
Monitor		15	1.5	0.1
Set-up		13	1.4	0.1
Harvest Map		5	1.8	0.4
Variety Map		3	1.7	0.6
Planter Adjustment		1	1.0	1.0
APEX		1	1.0	1.0

Only #1-3 Priorities for Each Customer	Each cell corresponds to an individual response	Count	AVG	Adj avg
Monitor		21	2.0	0.1
Set-up		21	2.0	0.1
Harvest Map		8	2.3	0.3
Variety Map		4	2.0	0.5
Planter Adjustment		1	1.0	1.0
APEX		2	2.0	1.0

Only #1-4 Priorities for Each Customer	Each cell corresponds to an individual response	Count	AVG	Adj avg
Monitor		28	2.5	0.1
Set-up		28	2.5	0.1
Harvest Map		10	2.6	0.3
Variety Map		6	2.7	0.4
Planter Adjustment		2	2.5	1.3
APEX		2	2.0	1.0

Master Customer Needs List

Only #1-5 Priorities for Each Customer	Each cell corresponds to an individual response	Count	AVG	Adj avg
Monitor		37	3.1	0.1
Set-up		34	2.9	0.1
Harvest Map		11	2.8	0.3
Variety Map		8	3.3	0.4
Planter Adjustment		3	3.3	1.1
APEX		2	2.0	1.0

APPENDIX B: INDIVIDUAL ROW CONTROL CUSTOMER SURVEY

Customer Focus Group Questions

13 February, 2009

NAME: ____

Date: ____

Dealer: ____

Planter Model: ___________________________________

PLANTER CLUTCH SYSTEM

1. What is the correct # of control sections?
2. Is individual row control up to 16 rows needed?
3. Do you have any concerns with the use of an electric clutch?
4. Is a clutch for vacuum and mechanical meters needed?
5. Is a clutch for Pro Shaft drive and chain drive meters needed?
6. What is the appropriate level of Swath Control accuracy?
7. Should planter clutch system be available as factory installed and bundles?
8. Are clutches needed on corn and soybean rows?
9. Is setup and manual control of clutches through the GS 2 display adequate?
10. Is a switchbox for manual control of row clutches needed?
11. Is the ½ width disconnect feature still needed with the use of Swath Control?
12. What $ value is individual seed meter control?

SERVICEABILITY

1. At start up or monitor power up, is it desirable to have some type of notification (visual, alarm) that the system is fully operational (i.e.. Like a self-test)?

- If the answer is "Yes", why?

- If the answer is "No", why?

2. With the row-unit clutch design that has been shown to you, is it acceptable to offer only a complete assembly for a service part?

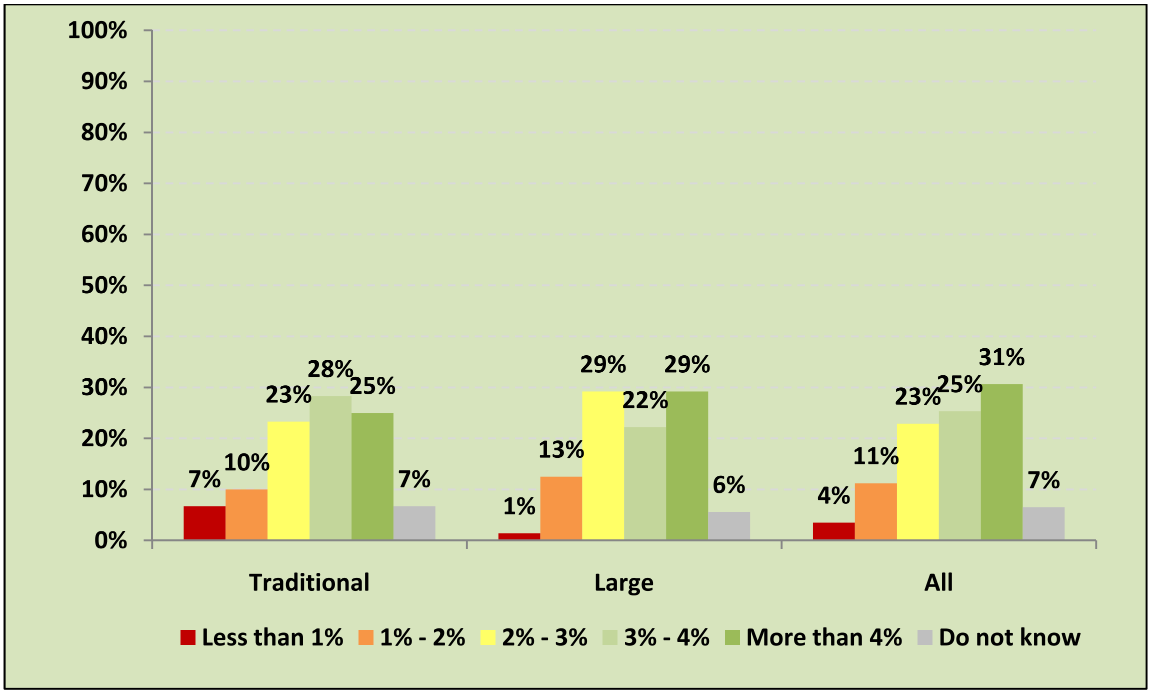
- If the answer is "Yes", why?

- If the answer is "No", why?

3. What type of notification is needed if/when a component of the system becomes inoperable? Keep in mind an electrical component failure will allow planting to continue.

4. If a component of the system becomes inoperable, should there be a "Diagnostic Tests" page in the monitor that would allow you to conduct system tests to determine the problem?

APPENDIX C: JOHN DEERE PANEL RESULTS



				JDPanel_Segments								
			Total	LPO	NAC	Public	ASP	PTP <$50K	PTP $50K+	Traditional	Large	XLarge
Planter_Savings.What would be your estimated seed input cost savings (percent) from using	Base		170	13	2	2	19	1	16	60	72	7
			--	--	--	--	--	--	--	--	--	--
	Less than 1%	COUNT	6	0	0	0	0	0	1	4	1	0
		COL %	3.5 %	0 %	0 %	0 %	0 %	0 %	6.3 %	6.7 %	1.4 %	0 %
	1% - 2%	COUNT	19	0	0	0	3	0	1	6	9	1
		COL %	11.2 %	0 %	0 %	0 %	15.8 %	0 %	6.3 %	10 %	12.5 %	14.3 %
	2% - 3%	COUNT	39	4	0	0	3	0	0	14	21	1
		COL %	22.9 %	30.8 %	0 %	0 %	15.8 %	0 %	0 %	23.3 %	29.2 %	14.3 %
	3% - 4%	COUNT	43	5	1	2	4	0	6	17	16	1
		COL %	25.3 %	38.5 %	50 %	100 %	21.1 %	0 %	37.5 %	28.3 %	22.2 %	14.3 %
	More than 4%	COUNT	52	3	1	0	9	0	6	15	21	4
		COL %	30.6 %	23.1 %	50 %	0 %	47.4 %	0 %	37.5 %	25 %	29.2 %	57.1 %
	Do not know	COUNT	11	1	0	0	0	1	2	4	4	0
		COL %	6.5 %	7.7 %	0 %	0 %	0 %	100 %	12.5 %	6.7 %	5.6 %	0 %

All	170
Large	72
Traditional	60

	Traditiona	Large	All
Less than 1%	7%	1%	4%
1% - 2%	10%	13%	11%
2% - 3%	23%	29%	23%
3% - 4%	28%	22%	25%
More than 4%	25%	29%	31%
Do not know	7%	6%	7%

APPENDIX D: SUMMARIZED FIELD DATA

Field Data Locations	Avg. Yield (bu/ac)	Average Down Force Margin (lbs)	Average Good Spacing	Average Singulation (%)	STDev Depth Values (Consistency)
Location 1	189.8	13.3	99.10%	97.00%	0.012
Location 2	200.4	3.5	98.50%	96.00%	0.011
Location 3	169.6	3.5	98.50%	96.00%	0.011
Location 4	162.7	9.4	98.60%	77.20%	0.02
Location 5	192.7	6.5	99.10%	98.20%	0.045
Location 6	167.5	14.3	99.00%	99.10%	0.014
Location 7	185.9	2	97.70%	98.50%	0.203
Location 8	169.8	2	97.70%	98.50%	0.203
Location 9	206.1	10.9	99.30%	95.60%	0.167
Location 10	204.5	10.9	99.30%	95.60%	0.167
Location 11	191.5	0.7	99.10%	99.50%	0.046
Location 12	173.8	6.9	99.50%	84.40%	0.103
Location 13	163.4	0.7	99.10%	94.50%	0.202
Location 14	178.8	10.5	99.10%	98.90%	0.005
Location 15	179.7	11.6	99.30%	99.30%	0.004
Location 16	204.1	20.9	99.20%	98.60%	0.013
Location 17	215.2	3.3	99.50%	94.70%	0.109
Location 18	202.8	13	99.70%	99.00%	0.147
Location 19	171	22	98.70%	98.40%	0.097
Location 20	127.8	22	98.70%	98.40%	0.097
Location 21	144.3	0.9	98.60%	99.40%	0.108
Location 22	176.9	1.2	99.30%	99.50%	0.429
Location 23	118.6	3	98.00%	96.90%	0.048
Average	178.13	8.39	99%	96%	0.10
Mean	178.80	6.90	99%	98%	0.10
Standard Deviation	24.52	6.91	0.5%	5.2%	0.10