ADOPTION OF NUTRIENT MANAGEMENT PRACTICES

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Doctor of Philosophy

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

ADOPTION OF NUTRIENT

MANAGEMENT PRACTICES

presented by Haluk Gedikoglu,

a candidate for the degree of doctor of philosophy,

and hereby certify that, in their opinion, it is worthy of acceptance.

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Professor Harvey James

Professor Peter Klein

Professor John Lory

Professor Raymond Massey

DEDICATED TO

My mother Gülsün Gedikoğlu and my father Sedat Gedikoğlu

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When I first started to study agricultural economics, my dream was to become a professor one day. I also dreamed very much about getting education in the United States, which I did not even think that it would be a Ph.D. Today, I am very happy that I have accomplished what I have dreamed about and even more. This would have been impossible, if I had not received the support that I got from my professors and my family.

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ABSTRACT

Off-farm income has recently been incorporated into the analysis of technology adoption, due to its increasing share in total farm household income in the U.S. Previous studies, however, found inconsistent results with respect to the impact of off-farm income on adoption of conservation practices. The contribution of the current study is to provide a conceptual model which shows that off-farm work has positive impact on adoption of capital incentive practices and negative impact on adoption labor intensive technologies. The results of multivariate probit regression confirms that adoption of injecting manure into the soil, which is a capital intensive practice, is positively and significantly impacted by off-farm work. However, adoption of record keeping, which is a labor intensive practice, is not negatively impacted by off-farm work. The current study also investigated whether insights from previous studies that analyzed primarily profit-oriented practices can be used when designing policies for conserving the environment, which is another contribution of the current study to the literature. The results from probit regressions show that there are some factors such as education and farm sales impact adoption of both types of practices in the same way, but there are also factors such as off-farm income that do not impact adoption of environment-oriented practices.

CHAPTER 1: INTRODUCTION

1.1. General Problem

The results of a water quality impairment survey show that agriculture accounts for 51 percent of the impaired rivers and 31 percent of impaired lakes in the U.S. (Environmental Protection Agency, 1998). According to the National Water Quality Inventory, animal feeding operations are significant sources of water pollution in the U.S (Environmental Protection Agency, 1998). Livestock production produces a by-product, manure, which contains nutrients such as nitrogen and phosphorous and without proper management, these nutrients can degrade water sources (Aillery *et al*., 2005). The National Water-Quality Assessment Program found that the highest concentration of nitrogen and phosphorus in streams occurred in basins with extensive agricultural production and that high nitrogen and phosphorus concentrations in these streams were mostly due to livestock wastes and manure and fertilizer used for crop production (U.S. Department of Interior, 1999).

Nitrogen is found in the environment and it is crucial for living organisms, especially as a nutrient for crops. The elemental nitrogen gas in the atmosphere is not hazardous to environmental quality. However, ammonia and the nitrate form of nitrogen are dangerous to environmental quality, as they can combine with other compounds and create environmental problems (Aillery *et al*., 2005). Nitrate is an important plant nutrient but in water sources it can cause over growth of plants, which causes the amount of dissolved oxygen required by fish and other organisms to decrease, causing the death of living organisms in water sources (a situation known as eutrophication). Nitrate can also be dangerous to human and animal health if it exists in high concentrations in drinking water (Aillery *et al*., 2005). The U.S. Environmental Protection Agency established the maximum amount of nitrate in drinking water as 10 parts per million (ppm). Livestock production contributes to emission of nitrate to water sources through the run-off or leaching of nitrate in manure, which is spread on fields, or through the leakage of manure storage facilities (Aillery *et al*., 2005). The manure that is produced on animal feeding operations (AFOs) that do not have enough land to apply manure at agronomic rates accounts for 60 percent of the manure nitrogen produced in U.S. This implies that there is nitrogen in excess of crop requirements, which increases the potential for water quality problems, unless this manure is provided to other farmers.

Phosphorus content of animal waste is also a concern for water sources (Environmental Protection Agency, 2006). AFOs are even less able to fully utilize the phosphorus than they are the nitrogen (Gollehon *et al.,* 2001). Phosphorus can reach surface water through runoff from land application of manure and direct disposition (Environmental Protection Agency, 2006). Once phosphorus reaches the surface water, it becomes available to aquatic plants and can also cause eutrophication (Environmental Protection Agency, 2006). Phosphorus is also a concern for drinking water. According to Bartenhangen *et al*., (1994), phosphate levels greater than 1.0 mg/l can interfere with coagulation in drinking water treatment plants.

Concentrated animal feeding operations (CAFOs), which concentrate animals, feed, manure and urine in the same land area, have been regulated since 1974 under the Clean Water Act (Gollehon *et al.,* 2001).[1] CAFOs are required to follow a comprehensive nutrient management plan (CNMP) that specifies the amount of manure applied to land to reduce the threat of nutrient leaching and run-off and the actions that will be followed to meet nutrient management goals and thus environmental goals (U.S. Department of Agriculture and Environmental Protection Agency, 1999). A CNMP should address manure handling and storage, land application of manure, feed management, and record keeping (U.S. Department of Agriculture and Environmental Protection Agency, 1999).

AFOs that are not classified as CAFOs are not federally regulated and are treated as non-point source polluters, therefore adoption of a CNMP, and the various manure management practices that comprise one, is voluntary. Since almost 95 percent of animal feeding operations are not classified as CAFOs, a majority of the animal feeding operations are not required to implement a CNMP. To minimize the pollution from AFOs, the U.S. Department of Agriculture and the Environmental Protection Agency promote the adoption of a CNMP by AFOs (U.S. Department of Agriculture and Environmental Protection Agency, 1999). Since adoption of manure management practices is voluntary for AFOs, understanding the factors that affect adoption is important in the design of successful policies and programs to improve water quality.

[1] According to EPA, the threshold for being considered as a CAFO is set by regulations based on the number of animals confined at the operation for a total of 45 days or more in any 12-month period such as 1,000 slaughter and feeder cattle, 700 mature dairy cows and 2,500 swine (Gollehon *et al*., 2001).

1.2. Specific Research Questions

- What are the farmer and farm characteristics that impact voluntary adoption of manure management practices?
- How do the perceptions of farmers about the manure management practices impact the adoption of practices?
- How does off-farm employment and off-farm income affect adoption of practices?
- Can we assume that the same factors affect adoption of practices with primarily on-farm benefits be used to design extension and cost-share programs for practices with primarily off-farm benefits?

In order to better understand livestock farming systems and the factors that may affect adoption of specific practices, information about manure handling systems and the manure management practices examined in this study is presented in the next chapter. The literature on adoption of new technologies is reviewed in chapter 3. Chapter 4 includes the methods and the data used in the dissertation. In chapter 5, the summary statistics is provided. Impact of off-farm income on adoption of nutrient management practices is analyzed in chapter 6. In chapter 7, the differences between environment-oriented and profit-oriented practices are analyzed. Conclusions are presented in chapter 8 of the dissertation.

CHAPTER 2: BACKGROUND

To provide a context for the variables used in the analysis, and the manure management issues faced by farmers more generally, this section provides background information. First, manure handling systems and how they are related to different livestock operations are analyzed. Then, descriptions of the specific manure management practices, focusing on their environmental impacts and implementation characteristics follows.

2.1. Manure Handling Systems

Urine and feces are produced by livestock. In pasture-based systems these are deposited directly on the soil and do not accumulate in a form that can be easily managed (Fulhage and Pfost, 2003; Pfost *et al.,* 2001). For confined animal feeding operations, both management of these by-products and the combination of these with the bedding material is called manure (Fulhage and Pfost, 2003; Pfost *et al.,* 2001). The production system affects the nutrient and dry matter content of the manure, hence the manure management system (Fulhage and Pfost, 2003; Pfost *et al.,* 2001).

Manure application equipment is determined by the solid content of the manure and manure is usually classified as solid, semisolid, slurry or liquid (Pfost *et al.,* 2001). In general, solid and semisolid are spread onto the fields, slurry is either broadcast on the field or injected into the soil and liquid manure is applied either by irrigation or injected into the soil (Pfost *et al.,* 2001).

2.1.1. Liquid manure and lagoon effluent

Lagoons are preferred by large size animal feeding operations to store high amount of manure (Pfost *et al.,* 2000). Manure can be stored in the lagoon until the lagoon effluent is applied to the land (Pfost *et al.,* 2000). Lagoons cause significant amount of nitrogen loses from manure to the air (Pfost *et al.,* 2000).

2.1.2. Slurry manure

Slurry systems are preferred when lagoon systems can not be built due to geological conditions (Pfost *et al.,* 2001). Slurry systems increase the amount of manure to be handled (compared with handling solids) due to higher water content, but making it possible to handle the manure as liquid is an advantage (Pfost *et al.,* 2000). As animal feeding operations become larger and potential odor and environmental problems become greater, there is a trend toward injecting or incorporating the slurry with a drag-hose, tractor-drawn applicator (Pfost *et al.,* 2000). Injection or immediate incorporation can prevent the loss of ammonia nitrogen to the air.

2.1.3. Solid and semisolid manure

Solid manure handling equipment may have lower capital costs and power requirements (Pfost *et al.,* 2000). However, the labor required for operation and management is generally greater than for other methods (Pfost *et al.,* 2000).

Livestock species also impact the type of manure management systems. The current study includes all major species of livestock, rather than focusing on only one type of specie or one type of animal feeding operation. Information about how animal specie impacts manure handling systems is given below.

2.1.4. Swine manure handling systems

Swine manure can be classified as slurry and it has 10 percent solid content (Fulhage and Pfost, 2001). Older swine operations have solid manure handling systems. Modern systems are the lagoon or slurry systems (Fulhage and Pfost, 2001). Slurry was more common in states like Iowa where manure had more value. Now most producers are putting in slurry systems because of increased fertilizer value and odor and other liabilities of the lagoon system.

2.1.5. Beef manure handling systems

Beef cattle manure can be handled as a solid, slurry or liquid (Pfost *et al.,* 2000). Beef manure has approximately 12 percent solid content, which is between semisolid and slurry (Pfost *et al.,* 2000). The manure handling systems are mostly for the feedlots and not for pasture based beef cattle operations (Pfost *et al.,* 2000). Manure incorporated into the bedding material or manure that is scraped can be spread onto the cropland or pasture (Pfost *et al.,* 2000).

2.1.6. Dairy manure handling systems

Dairy manure can be handled as solid, slurry or liquid (Pfost and Fulhage, 2004). Many dairy operations use more than one system. Solid systems are commonly used in smaller operations and larger operations prefer lagoon systems (Pfost and Fulhage, 2004).

2.1.7. Poultry manure handling systems

Poultry manure has approximately 25 percent solid materials (Fulhage and Pfost, 1994). Broiler or turkey manure is typically handled as solid and surface applied to cropland (Fulhage and Pfost, 1994).

2.2. Manure Management Practices

Nutrient management should prevent the application of nutrients at rates that exceed the capacity of the soil and the anticipated needs of crops (U.S. Department of Agriculture and Environmental Protection Agency, 1999). A variety of manure management practices can contribute to improved water quality. According to the U.S. Department of Agriculture and Environmental Protection Agency (1999), effective use of manure as fertilizer requires five steps:

1. Testing manure for nutrient content,
2. Estimating nutrient availability to crops,
3. Determining an application rate based on crop need for nutrients,
4. Calibrating spreaders to provide the target application rate and
5. Using a uniform spreading pattern.

To determine nutrient needs and content, soil and manure should be tested and nutrient needs of the crop should be evaluated. Manure application equipment should be calibrated to ensure that the intended quantity of material is being applied. Records of crop removed annually and the total amount of manure applied should be kept to maintain the desired nutrient balance. Information about the manure management practices and how they differ in terms of labor versus capital intensity and environment versus profit oriented is reviewed next.

2.2.1 Calibrating manure spreaders

Increasing environmental concerns and the need to match the nutrients from manure to the nutrient needs of crops force farmers to carefully measure the manure spread onto the land (Fulhage, 1994a). To obtain the correct manure application rate it is important to correctly set the manure spreader and arrange the correct operating speed and travel lane spacing (Fulhage, 1994a). Determining these factors is called "calibrating" the manure spreader (Fulhage, 1994a). Calibrating the manure spreader controls the quantity and uniformity of the manure leaving the manure applicator.

Calibrating the manure spreader should be done annually or when the spreader is changed (U.S. Department of Agriculture, 1996). There are two main methods for calibrating manure spreaders; load-area calibration and weight-area calibration. The load-area calibration method requires measuring the amount of manure in the manure spreader and measuring the total area over which manure is spread and then calculating the amount of manure spread per acre (U.S. Department of Agriculture, 1996). The first step is to measure the capacity of the manure spreader. For liquid manure spreaders, the manufacturer provides the volume. For solid and semi solid manure spreaders, the spreader should be weighed empty on a farm scale and then weighed again with the manure loaded. The difference of the two measures will be the weight of the manure on the spreader. The second step is to spread the manure onto the field. The third step is to measure the area of the field that the manure was spread. It is recommended that two or three loads of manure be spread on a field and their averages taken. The last step is to calculate the application rate by dividing the amount of manure spread by the area of the land covered to find the amount of manure applied per acre. This procedure is repeated again until the desired manure per acre rate is reached or a relationship is developed between varied applicator settings and the resulting application rate. The weight-area method requires laying a sheet on the ground with known measurements and spreading the manure on to the sheet and then calculating the per acre manure application rate (U.S. Department of Agriculture, 1996).

Given the procedures required to calibrate a manure spreader, this practice is expected to be relatively labor or time intensive. Calibrating the manure spreader will impact both environmental quality and profitability of the farm. Hence, this practice is both environment and profit-oriented. If manure nutrients exceed crop requirements and if the farmers can not sell the excess manure or can not use the excess manure in another profitable activity, the profitability aspect of calibrating manure spreaders will be less important than the environmental quality aspect.

2.2.2 Grass filter strips

A grass filter strip is used around water sources to protect the water source from nutrient run-off that can be caused after manure or fertilizer application to the field (Nakao, *et al*., 1999). This system decreases the speed of flow, allowing particulate matter to settle out, as well as filtering nutrients out. The grass filter will reduce the amount of nutrients such as nitrogen, phosphorus and potassium that will reach the water source with the run-off water from the field (Nakao, *et al*., 1999).

The costs associated with grass filter strips are; land rental costs, seed and fertilizer costs, and equipment and labor costs (Nakao, *et al*., 1999). Land rental costs are the cost of removing the land from crop production. Therefore, the land rental cost is the revenue forgone from the soybeans, corn or other crop production that was originally received from the area before the grass filter strip was established (Nakao, *et al*., 1999). The type of tillage system used during the establishment of grass filter strip impacts the equipment and labor costs. Nakao, *et al*., (1999) found the average equipment and labor costs to be $22 per acre using a no-till system and $33 per acre using a conventional tillage system for Ohio.

The land rental rate is the most important cost factor associated with grass filter strips (Nakao, *et al*., 1999). The yield per acre was 38 bushels per acre for soybeans and 138 for corn, for seed, for Missouri in 2006. The average value per bushel was $6.30 for soybeans and $3.10 for corn in 2006 (Missouri Department of Agriculture, 2008), the year the survey was conducted. The variable cost is reported as $90 soybeans $201 for corn and for Heartland region in 2006 (U.S. Department of Agriculture, 2006). Value of production less operation costs is thus $180 for soybeans and $286 for corn. (Prices for crops produced in the Midwest, as well as variable costs such as fertilizer, are higher now.) According to Nakao, *et al*., (1999) a grass filter strip does not have any harvest benefit and the only benefit is the payment from a cost share program, such as EQIP. Since the costs associated with a grass filter system do not include any up-front capital equipment cost, or fixed costs, it is expected that the grass filter system is intermediate for being a capital intensive practice. Once established, labor costs for grass filter strips are relatively low so it primarily reduces profitability and represents an on-going or variable cost. Hence, this practice is also intermediate for being a labor intensive practice. Due to the opportunity cost or the land rental rate of having a grass filter system, it is expected that a grass filter system is not a profit oriented practice, but it is an environment oriented practice.

2.2.3 Record keeping

Record keeping can help to guarantee that the land application of manure uses the manure's fertilizer nutrients efficiently and protects the ground and surface water sources (Fulhage, 1994b). The information kept in records can be for; field identification, year, crop grown, crop yield, soil test results, commercial fertilizer applied, manure test results, manure application method, manure sold and soil and weather conditions (Fulhage, 1994b). Some of the information that should be included in the records for a CNMP is (U.S. Department of Agriculture and Natural Resources Conservation Service, 2003):

- Results of manure tests.
- Results of soil tests.
- Manure and commercial fertilizer application records:
    - Fields of application,
    - Application amounts,
    - Date of applications,
    - Weather conditions,
    - Soil condition,
    - Application method.
- Dates for crop planting and harvesting.
- Manure storage:
    - Dates of emptying and levels before and after emptying,
    - Discharge and overflow.
- Transfer of manure off the farm.
- Calibration of manure spreaders.

Some of the information should be recorded annually is; soil tests, manure tests and nutrient budgeting. The information that should be kept more frequently is manure application records, manure transfer, containment structure reports and operation and maintenance reports (Iowa State University, 2003). Given the information that is required for record keeping, it is expected that record keeping is relatively labor or time intensive. The information kept in records can be used both towards profitability of the farm (since it enables more efficient fertilizer use) and environmental quality. However, if the records are kept primarily for CNMP purposes, then record keeping can be classified as environment oriented.

2.2.4. Manure testing

To make efficient use of fertilizer nutrients in manure, nutrient levels must be determined by laboratory analysis (Fulhage, 2000). Laboratory tests typically determine ammonia, total Kjeldahl nitrogen total phosphorus and total potassium (Fulhage, 2000). Organic nitrogen is obtained by subtracting ammonia nitrogen from total Kjeldahl nitrogen (Fulhage, 2000). Plant available nitrogen can then be estimated from this estimate of ammonia and organic nitrogen (Fulhage, 2000). Total phosphorus and potassium are considered 100% plant available and can substitute 1:1 for recommended fertilizer (Fulhage, 2000. The opportunity cost of not having manure testing is high, since unnecessary amounts of fertilizer might be applied to the soil (U.S. Department of Agriculture, 1996). Taking a representative sample is important for manure testing. Samples from different parts of the pile of solid manure should be taken (U.S. Department of Agriculture, 1996). For liquid manure, the lagoon should be agitated before taking the sample. It is expected that manure testing is neither labor nor capital intensive. The cost of a manure analysis is about $40 (more with labor, postage, and equipment). Since the information from manure testing can be used for saving fertilizer cost and preventing over application of manure, it is expected that manure testing can be both environment and profit-oriented.

2.2.5. Soil testing

Soil testing is done to measure the fertility of soil and to determine the amount of manure or fertilizer to be applied (U.S. Department of Agriculture, 1996). Since the soil sample will represent the whole field, taking the sample should be done very carefully. If the field has sections with different slope, drainage or soil, then the field should be divided into sections (U.S. Department of Agriculture, 1996). For each section of the field, 20 or more samples should be taken and then these samples should be mixed in a clean plastic pail for each section of the field and then sent for the laboratory analysis (U.S. Department of Agriculture, 1996). University extension services and fertilizer dealers have laboratories for soil testing (U.S. Department of Agriculture, 1996) and cost is $7 per sample (field or portion of a field). No large equipment is needed, only a soil sampler that costs less than $100. Also, since soil testing is typically done every three or four years it isn't particularly time intensive. Hence, soil testing is neither capital nor labor intensive. It is a profitable practice since it can save on fertilizer costs.

2.2.6 Maintaining a setback

Maintaining a setback between manure application areas and streams and lakes decreases the contamination of these resources with the nutrients carried by ground and surface water (Cromley and Lory, 2006). The recommended distance of a setback between the cropland and the water source is 100 feet (Cromley and Lory, 2006). Since the cropland will not receive any fertilizer or manure (the setback does not receive manure, it can receive fertilizer), the yield from this field will be lower than those from other parts of the field (but not if the farmer fertilizes). For this reason, maintaining a setback is expected to be an environment oriented practice. This practice requires neither an up-front investment nor labor. Therefore, this practice is expected to be neither labor nor capital intensive.

2.2.7. Injecting manure into the soil

Injecting manure into the soil minimizes nitrogen losses and odor problems (Prairie Agricultural Machinery Institute, 1997). The nutrient loss can be minimized to as low as 1%, whereas with sprinkler irrigation, nutrient loss can range from 20 to 90% (Prairie Agricultural Machinery Institute, 1997). The disadvantage of manure injection systems is the cost of the required equipment. The main equipment types required for manure injecting systems are; an agitator that agitates the manure in the manure storage unit, the main line that transports the manure from storage to the field, a pump that is connected to the main line and the storage, the drag line that transports the manure from main line to the manure injector, an injector that injects the manure into the soil, and three tractors (Prairie Agricultural Machinery Institute, 1997). The tractors will be connected to the agitator, the drag line and to the injector. Depending on the size of the farm, the cost of purchasing equipment other than the three tractors can range from $60,000 to $120,000 (Prairie Agricultural Machinery Institute, 1997). Due to the costs associated with manure injecting systems, injecting manure is assumed to be a capital intensive technology. Although the value of the nutrient loss that is avoided by injection decreases the overall cost of manure injection system, it is expected that manure injection systems are costly and done for profit reasons.

2.2.8. Roundup Ready soybeans

The Roundup Ready gene in the Roundup Ready soybeans allows resistance to the herbicide Roundup (Couvillion *et al*., 2000). Hence, when Roundup is sprayed on Roundup Ready soybeans, Roundup sensitive weeds are killed without harming the soybean crop (Couvillion *et al*., 2000). According to Couvillion *et al*., (2000), Roundup Ready soybeans will allow farmers to decrease their chemical application costs and also the costs of trips to the field to apply herbicide. According to Monsanto (2006) conducted trials, Roundup Ready soybeans are expected to increase yields by 4.5 bu/acre over conventional herbicide systems. The study by Sydorovych and Marra (2008) shows that when farmers chose their herbicide, they consider both the application costs and the risk to the surface water quality. It is expected that Roundup Ready soybeans is primarily adopted to reduce costs and increase profitability. Therefore, it is assumed to be a profit oriented practice. However, it is also expected that farmers can consider the benefit of Roundup Ready soybeans to the environment (since Roundup has relatively fewer negative environmental effects than other herbicides) when they adopt this practice. Since this practice does not require any upfront investment and decreases labor costs, we assume this practice to be neither capital nor labor intensive.

The voluntary adoption of CNMPs and the manure management practices that are components of a CNMP by AFOs requires the barriers to voluntary adoption to be known by policy makers, technical staff and extension educators. To identify these barriers, the literature on adoption and diffusion of new technology is reviewed in the next chapter.

CHAPTER 3: LITERATURE REVIEW

The literature on adoption and diffusion of new technologies is reviewed in this section. The literature on technology adoption is reviewed both in historical order starting from the seminal study by Griliches (1957) and in relevance to the current study. The seminal study by Griliches (1957) spawned the theory that analyzes diffusion of technology. The underpinnings of diffusion theory caused studies to focus on micro-level decisions and to develop adoption theory. Since there are many different factors that impact adoption of a new technology, the studies mostly analyzed a subset of factors and developed theories that combine this small set of factors and adoption behavior. Therefore, instead of a one big theory that explains all aspects of technology adoption, it is possible to see different theories that explain a part of adoption behavior. The historical order of the development of adoption theories had been roughly in order of profitability, farm size, risk and uncertainty, information, human capital and labor supply. Therefore, this order will be followed in reviewing the theoretical studies. The other factors that are found to be important in the adoption literature and relevant to the current study are also reviewed.

Since the “innovation” or “new technology” is the core of the adoption behavior, the review starts with the literature on innovation and subsequently the literature on diffusion and adoption of new technology are reviewed.

3.1. Innovation

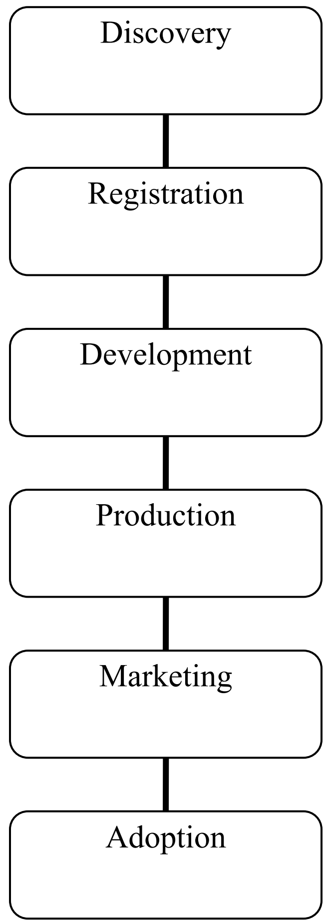
The process of innovation is the root of the studies of adoption and diffusion of new technologies. Rogers (2003) defines an innovation as “an idea, practice, or object that is perceived as new by an individual or other unit of adopter”. Innovations can be grouped as *embodied* in a capital good (such as variable inputs and farm machinery) and *disembodied* (such as conservation practices) (Sunding and Zilberman, 2001) Embodied innovations are generally developed by the private sector, since they are profit-oriented innovations. However, disembodied innovations require public sector investment, since they are not profit-oriented and the private sector would not invest in these innovations. The distinction between embodied and disembodied innovation is helpful, since incentives to adopt these innovations by potential users may be different.

Although some innovations may emerge randomly, Hayami and Ruttan (1985) show the emergence of an innovation as a response to economic conditions. Emergence of environmentally friendly technologies when environmental regulations are strict and emergence of water saving technologies when there are water shortages, can be examples of induced innovations (Sunding and Zilberman, 2001). There are several stages between generation of an innovation and its adoption by actual users (Sunding and Zilberman, 2001). These stages are depicted in Figure 1.

In the discovery stage the innovation emerges as a concept. The patent is received for the concept in the registration stage. In the development stage the discovery moves from laboratory to field. The innovation is then produced and subsequently marketed (Sunding and Zilberman, 2001).

Once the innovation is marketed there can be a time lag between the introduction to the market and actually being used by the potential users (Rogers, 2003; Sunding and Zilberman, 2001).

Figure 1. Stages of Innovation Generation (Sunding and Zilberman, 2001)



3.2. Diffusion and Adoption

In agriculture, immediate and uniform adoption of a new technology by farmers happens very rarely (Feder, *et al*., 1985). Feder, *et al*. (1985) explains the delay in adoption and non-adoption by factors such as credit constraints, limited access to information, risk aversion, inadequate farm size, inadequate human capital and inadequate incentives due to tenure arrangements. The time lag between marketing of an innovation and its actual use by potential users, cause adoption and diffusion studies to emerge (Rogers, 2003).

Adoption studies analyze which factors affect an individual's decision as to whether to use an innovation and when to start using it (Sunding and Zilberman, 2001). Rogers (2003) defines the adoption process as "the mental process an individual passes from first hearing about an innovation to final adoption". However, a quantitative definition of adoption is required for theoretical and empirical analysis (Feder, *et al*., 1985). Sunding and Zilberman (2001) provide measurement of adoption both as a discrete choice and a continuous variable. In the discrete choice, adoption of an innovation occurs if the individual uses the innovation. An example for this kind of adoption can be adoption of manure testing as a conservation practice or purchase of a new variety of farm machine. As a continuous variable, adoption can show to what extent the indivisible innovation is adopted, such as what percent of the farmer's land is planted with the new variety of seed.

In contrast to adoption studies, diffusion studies analyze the adoption of a technology in a region or population (Feder, *et al*., 1985; Sunding and Zilberman, 2001). Rogers (2003) defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system." Rogers (2003) mentions diffusion as a process by which an alteration occurs. Feder, *et al*. (1985) and Sunding and Zilberman (2001) define diffusion as the aggregate adoption in a region or population. One measure of diffusion may be the percent of potential users that adopted the innovation in a region or population. An example can be the percentage of farmers who adopted a nutrient management practice in Missouri.

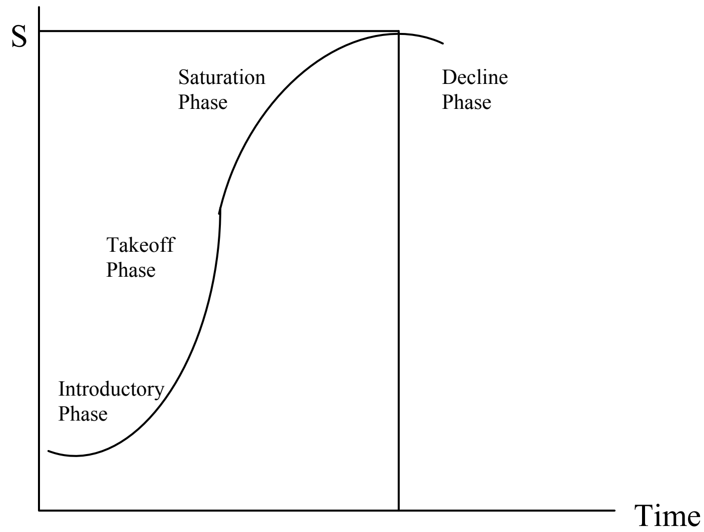
3.3. Diffusion of Technology

Griliches (1957) analyzed the diffusion of hybrid corn in the U.S. states from the 1930's to the 1950's. The study found that the diffusion of hybrid corn was an S-shaped function of time. The analytical form of the diffusion curve is estimated by Griliches (1957) using a logistic function of the form:

(1) $Y_t = S[1 + e^{-(a+bt)}]^{-1}$

Y_t is the diffusion of innovation at time t, S is the saturation rate of the diffusion (can be 100% or a constant), a reflects the diffusion rate at the start of diffusion period (i.e. $t = 0$), and the value of b changes the shape of the diffusion curve (Sunding and Zilberman, 2001). The shape of S-shaped diffusion curve is depicted in Figure 2.

Figure 2: S-Shaped Diffusion Curve (Sunding and Zilberman, 2001)



The S-shaped curve shows that initially the overall adoption is low but the rate of adoption increases as the introductory phase ends. After the introductory phase, the rate of adoption increases rapidly during the takeoff phase and slows down when the saturation phase starts. The shape of the curve becomes like a concave function when the saturation phase starts. After the saturation level *S* is reached, the rate of adoption decreases in the decline phase, where adoption of another technology starts (Sunding and Zilberman, 2001; Cox, 1967).

Griliches (1957) found that the parameters of equation (1) are impacted by economic factors such as the difference in profitability of hybrid and traditional corn and size of the farms in different counties. All three parameters *S, a, b* are positively correlated with the percentage difference in profitability between the hybrid and traditional corn (Griliches, 1957). The study by Griliches (1957) will be further analyzed in the section on profitability of the new technology.

3.3.1. Theoretical diffusion models

There have been theoretical studies to explain the findings of the S-Shaped diffusion curve. Mansfield (1963) assumes diffusion is a process of imitation. According to his model, the diffusion path for an industry is:

(2) $$\frac{\partial Y_t}{\partial t} = bY_t\left(1 - \frac{Y_t}{S}\right)$$

where $\frac{\partial Y_t}{\partial t}$ is the adoption rate at time *t*, Y_t is the diffusion level at time *t*, $\left(1 - \frac{Y_t}{S}\right)$ is the remaining diffusion level between time *t* to saturation level *S* and *b* is a coefficient. In this model, the adoption rate is impacted by the aggregate level of adoption until time *t*. Hence, if the aggregate level of adoption had been low, the rate of adoption will be rapid at time *t*, and if the aggregate adoption had been high, the rate of adoption will be low at time *t*, which will give the S-Shaped curve. Studies by Lehvall and Wahlbin (1973) and Hernes (1976) incorporated factors such information gathering, risk aversion and wealth into the model of Mansfield (1963). However, these studies did not provide an explanation for individual decision making, which caused criticism of these models and emergence of the threshold model (Sunding and Zilberman, 2001).

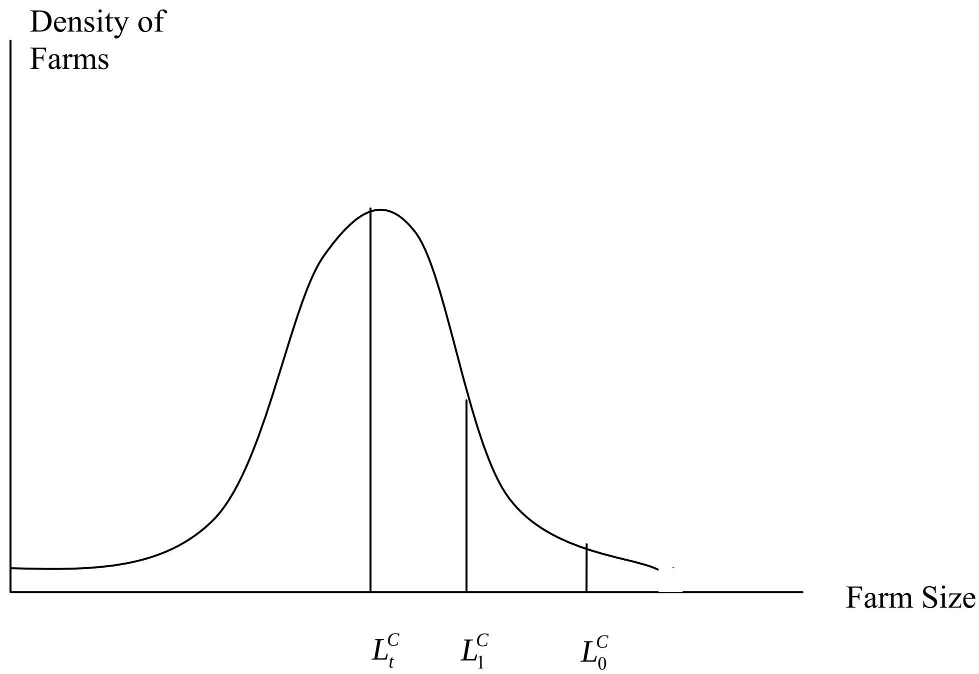
3.3.2. The threshold model of diffusion

Threshold models assume heterogeneity among decision makers and that decision makers behave strategically (e.g. are profit maximizers). Sunding and Zilberman (2001) give an example of a threshold model for the case where the heterogeneity among farmers stems from the farm size. In this model it is assumed that there is a critical level of farm size L_t^C, which is a function of fixed cost of adoption of new technology, F_t, and the percentage difference between the profit levels of the new technology and traditional technology, $\Delta\pi_t$. The adoption of the new technology will occur for the farms with farm size above the critical farm size level, L_t^C.

(3) $L_t^C = \dfrac{F_t}{\Delta\pi_t}$

The model assumes that, over time either the fixed cost of adoption will decrease or the percentage difference in profits levels will increase, hence causing the critical level of farm size to decrease over time for adoption. The price of the fixed cost will decrease over time, because adoption of the new technology may require indivisible farm equipment or up-front costs of information and these costs may decline by knowledge accumulation (Sunding and Zilberman, 2001). The profit differential will increase over time, because as farmers adopt the technology, they get more experience in using the new technology, hence increase the return from adoption over time by *learning by using*. As shown in Figure 3, over time the critical farm level decreases, causing more and more farms to adopt the new technology.

Figure 3: The Threshold Model of Diffusion (Sunding and Zilberman, 2001)



In Figure 3, L_0^C is the threshold farm size for adoption when the technology is first introduced and L_1^C is the threshold after one year passed from the introduction of the technology. The number of farms and the density of farms, which adopt the new technology increase over time as the threshold decreases.

3.4. Theoretical Models of Adoption

The threshold model of technology diffusion changed the focus of studies from overall adoption of technology to search for heterogeneity among individuals and to analyze individual decision making, hence to studies of adoption (Sunding and Zilberman, 2001). The differences in adoption behavior of individuals can be attributed to factors such as aversion to risk, limited access to credit, inadequate farm size, insufficient human capital, insufficient information about the new technology and labor shortages (Feder, *et al*., 1985).

3.4.1 Profitability

The early studies by Griliches (1957) and Mansfield (1961) on diffusion of new technology have emphasized the importance of the profitability of new technology on adoption. These studies have analyzed mainly the factors impacting adoption of a new technology. Both studies have confirmed that the adoption of new technology increases among potential users as shifting from old technology to new technology becomes more profitable.

Griliches (1957) analyzed the diffusion of hybrid corn in the U.S. states over 1930's and 1950's. Hybrid corn technology is a method of breeding superior corn for specific localities and the superiority is measured by average increase in yield of corn per acre (Griliches, 1957). However, there is a time lag between when hybrid corn becomes first available in a state and it is first used by the farmers in that state. There is also a difference among states in terms of the time when most of the farmers use hybrid corn (Griliches, 1957). It is hypothesized that the adoption of hybrid corn is a function of profitability of the shift from local variety to hybrid corn, due to the increase in yield attained by hybrid corn. The regression results show that the variation in adoption of hybrid corn can be explained by the profitability of the shift to hybrid corn, which is measured by average increase in yield per acre, and average corn acres per farm (Griliches, 1957).

Mansfield (1961) analyzed the diffusion of 12 new technologies across 4 different industries in the U.S. over the 1940's[2]. The data shows that the diffusion of these technologies took a long time overall but there are significant differences between technologies and the main question addressed in this study is why the firms were slow in adoption of some new technologies and quick in others. Mansfield (1961) shows theoretically that the adoption of the new technology depends on the profitability of adoption, size of investment required for adoption, the proportion of firms that already adopted the new technology and other unspecified variables. The data analysis confirms that as the profitability of the new technology over the old technology increases, firms become more likely to adopt the new technology. However, as the initial investment cost of adoption increases, firms become less likely to adopt the new technology. Mansfield (1961) notes that the uncertainty associated with the profits of new technology and how fast this uncertainty drops can also impact the adoption of new technology.

Some studies on adoption of new technology have found results confirming the findings of Griliches (1957) and Mansfield (1961), that the adoption of new technology increases with the profitability. However, there are also other studies which found that a new technology may not be adopted even if it has higher returns than the traditional technology. The contrary results show that there are factors other than profitability that also impact the adoption decision, which also lead to theoretical studies that attempt to explain adoption of new technology with human capital, labor supply, risk and

[2] The technologies and industries are the shuttle car, trackless mobile loader, and continuous mining machine for coal industry; the by-product coke oven, continuous wide strip mill, and continuous annealing line for tine plate for iron and steel industry; the pallet-loading machine, tine container, and high-speed bottle filler for brewing industry; the diesel locomotive, centralized traffic control and car retarders for railroad industry (Mansfield, 1961).

uncertainty, and so on. Some empirical findings of these studies are discussed next in two separate groups; profitability leads to adoption and profitability does not lead to adoption.

Koundouri, *et al*. (2006) analyze the adoption of irrigation technology in Crete, Greece and they found that as the expected profit of adopting the irrigation technology increases, farmers become more likely to adopt the irrigation technology. Rahm and Huffman (1984) found that as the expected profitability of reduced tillage per acre increases, corn enterprises are more like to adopt reduced tillage. Barham, *et al*. (2004) analyze adoption of recombinant bovine somatotropin (rBST), which is a productivity enhancing hormone that is injected in cows, by dairy farmers in Wisconsin during 1994-2001. Their results show that the adoption of rBST increases as the farms have access to complementary feeding technologies, which increase the profitability of rBST. Hua, *et al*. (2004) analyze both adoption of conservation tillage and participation in a conservation program among Ohio farmers. Their results show that there is a positive and significant relationship between farmers' perception that conservation practices are profitable and farmers' adoption of conservation tillage. Khanna (2001) analyzes adoption of variable rate technology (VRT), which is used for site-specific input application, in Iowa, Illinois, Indiana and Wisconsin in 1997. The results of this study show that adoption of VRT is negatively related to the cost of adoption. Overall the studies mentioned above confirm that adoption of new technology is positively related to the profitability of that technology.

Some of the studies that found profitability of the new technology is not sufficient for its adoption are discussed next. Carey and Zilberman (2002) analyze the adoption of modern irrigation technologies among Californian farmers. Their results show that even if the expected profits are higher with the modern irrigation technologies than with traditional irrigation technologies, many farmers have not adopted the modern irrigation technologies. Soule, *et a*l. (2000) show that renters are less likely to adopt practices with benefits observed in the long-term. Qaim and de Janvry (2003) analyze adoption of Bt Cotton in Argentina. Bt Cotton has higher yield than traditional cotton, however adoption of Bt Cotton has been low in Argentina unlike in other countries (Qaim and de Janvry, 2003). Qaim and de Janvry (2003) show that the high price for Bt Cotton is an obstacle for farmers to adoption Bt Cotton, even if it has higher yield than the traditional cotton. Abdulai and Huffman (2005) analyze adoption of crossbred-cow technology by Tanzanian farmers. Even if crossbreeding is a profitable technology, its adoption in Tanzania has been low. Abdulai and Huffman (2005) showed that the adoption of crossbred-cow technology by Tanzanian farmers is delayed by the current price of the new technology. Moreno and Sunding (2005) found the fixed investment cost of adoption has large negative effect on the adoption of modern irrigation technologies; drip technology, gravity technology and sprinkler technology.

The non-adoption of profitable technologies has further expanded the analysis of factors beyond profitability. Some of these factors defined in the literature are the farm size, aversion to risk, yield uncertainty, human capital and off-farm work. Among these factors, farm size had been the first analyzed factor to bring explanation to non-adoption of profitable technologies. The non-adoption of high yielding variety crops during the "green revolution" and different adoption decisions between small and large farms had made the focus of the analysis the size of the farm (Feder, *et al*., 1985).

3.4.2 Farm size

Farm size has been included in the analysis of adoption of new technology due to its relation with fixed investment cost, credit constraint, risk aversion, information cost, human capital and off-farm income (Feder, *et al*., 1985). We can analyze the impact of farm size on adoption of new technology, through its association with different factors. Economies of scale in production imply average fixed costs decrease as the farm size increases. Access to credit is improved with increased farm size. Economies of scale in information costs imply lower average costs of obtaining information related to the new technology. Human capital theory asserts that the opportunity cost of not adopting the technology is higher for bigger farms, hence the incentive to adopt to new technology is higher for larger farms as they benefit more from new technology due to higher production. Off-farm income is assumed to be negatively associated with farm size. This is because larger farms will require more on-farm work and leave less time available for off-farm work. Risk aversion and farm size are related since it is expected that smaller size farms may adopt the new technology more intensively (on a higher share of the total land), whereas larger farms may adopt the technology less intensively but with higher quantities.

The results of early studies on adoption of new technology by Griliches (1957) and Mansfield (1961) have showed the positive relation between adoption of new technology and size of production. Some studies found results that confirm adoption of new technology increases with farm size, whereas others found that the adoption of new technology is not related to farm size. The studies that confirm the relation between farm size and adoption are reviewed next, and then the studies that do not confirm this relation are reviewed.

The study by Rahm and Huffman (1984) found that larger farms are more likely to adopt reduced tillage, as the expected profitability increases with size. Qaim and de Janvry (2003) show that Bt cotton is more likely to be adopted by large farmers, due to high costs of adoption. Hence, large farms benefit from economies of scale. Barham, *et al*. (2004) found that adoption of rBST increases as the size of the farm increases, as the price of the rBST was high, only large farms could afford it. Abdulai and Huffman (2005) found that as the size of the farm increases, the adoption of cross-bred technology will be faster. This finding is consistent with economies of scale, hence less relative risk exposure for larger farms (Abdulai and Huffman, 2005). The results of Khanna (2001) showed the adoption of variable rate technology, which is a technically more sophisticated technology, is impacted positively by the farm size. This may be due to returns to scale due to fixed costs of the equipment (Khanna, 2001). Hua, *et al*. (2004) found that the number of conservation programs the farmers participate in is positively and significantly related to farm size. Chang and Boisvert (2005) analyzed farmers' participation in the Conservation Reserve Program (CRP) and their results show the probability of participation in CRP increases with farm size. Soule, *et. al*. (2000) found adoption of conservation tillage, with benefits realized in the short term, is positive and significantly related to farm size. Soule, *et. al*. (2000) attributes this result to economies of scale.

The studies that found either statistically insignificant or negative relationships between farm size and adoption of new technology are reviewed next. The results of

Khanna (2001) showed that number of acres cropped by a farmer has an insignificant impact on adoption of soil testing. This is because soil testing is a scale neutral technology (Khanna, 2001). Hua, *et al*. (2004) found a statistically insignificant but positive relation between farm size and adoption of conservation tillage. The study by Koundouri, *et al*. (2006) found that smaller farms are more likely to adopt the new technology, but their analysis show that the average profitability is higher among small farms than large farms in the sample. Soule, *et. al*.(2000) found that adoption of conservation practices; grassed waterways, strip cropping and contour farming, which have benefits only realized in the long-run are negatively and significantly related to farm size. However, this relation becomes statistically insignificant when adopters are classified as owner and renters. This result may show the impact of farm size is different for owners and renters. The negative relation between farm size and adoption of these practices is, because these practices do not offer economies of scale (Soule, *et al*., 2000).

The impact of access to credit, which is hypothesized to be easier for larger farms, on adoption of new technology is analyzed in some studies. Some of the empirical results are reviewed here. Qaim and de Janvry (2003) found that Argentinean farmers that have a credit constraint are less likely to adopt Bt Cotton and the result is statistically significant. Abdulai and Huffman (2005) found that the improvement in farmers' access to credit will enhance the diffusion of crossbred-cow technology by Tanzanian farmers. Carey and Zilberman (2002) show that reduction of the taxes for initial investment costs of modern irrigation technologies will act like a source of credit, hence increase the adoption of the modern technologies.

Besides the farm size, other farm characteristics are also found to be significant in adoption of new technology. The results of some studies are as follows. Moreno and Sunding (2005) found farm characteristics such as soil permeability and slope impacts on adoption of irrigation technology. Chang and Boisvert (2005) shows that the probability to participate in CRP increases as the proportion of land classified as high quality increases. Their analysis also shows that the type of crop production impacts farmers' participation in environmental programs. Due to the high opportunity cost of land for vegetable producers, they are found to be less likely to participate in CRP than cash crop producers (Chang and Boisvert, 2005). Hua, *et al*. (2004) found that there is no statistically significant relationship between type of crop planted and participation in a conservation program. However, adoption of conservation tillage decreases as the share of animal production and high value crops, fruit and vegetables, increases in total farm sales. Khanna (2001) found that the adoption of soil testing and variable rate technology are positively correlated with soil quality of the farms.

Theoretical studies that stemmed from non-adoption of profitable technologies during the "green revolution" started with analyzing the impact of risk and uncertainty on adoption of new technology and incorporating farm size and credit constraints into the analysis. Following these models, the models that analyze the impact of information on the uncertainty created by adoption of new technology are developed. After that, studies on human capital are also developed. These studies are reviewed following the order risk and uncertainty, information gathering and human capital.

3.4.3. Risk

Adoption of new technology can introduce risk to farm production (Sunding and Zilberman, 2001). During the "green revolution" it was observed that some profitable technologies are adopted by only large farms, but other profitable technologies are adopted more intensely by smaller farms than large farms (Feder, *et al*., 1985). Roumasset (1976) emphasizes that the incomplete adoption of high-yield seed varieties during the "green revolution", was due to the yield risk introduced by these varieties. Even if the expected yield was higher, the variance of the yield was also higher, which means higher risk is introduced by adoption.

The model of farmer's decision making under risk can be derived from static expected utility maximization subject to technological, institutional and labor constraints, where the farmer decides whether or not to adopt the technology at all (Feder, *et a*l., 1985; Sunding and Zilberman, 2001). The decision of the farmer as to what extent to adopt a new technology (e.g. what percent of the land to convert to a new production system) can be modeled as a continuous optimization problem (Sunding and Zilberman, 2001).

For a given period, the decision making process of a farmer about how many acres of land to allocate to the new technology can be represented by maximizing the expected utility from adoption of the new technology (Sunding and Zilberman, 2001). Similar models have been used to analyze the investment in risky assets (Mas-Colell, *et al*., 1995).

The relation between risk aversion and farm size and the exogenous credit constraint is modeled by Feder (1980). The model analyzes the adoption of the modern crop variety which has higher yield than the traditional crop variety. However, the modern crop variety has uncertainty in terms of yield, whereas the traditional crop variety has no yield uncertainty. The uncertainty can stem from the farmer's unfamiliarity with the new crop variety and the new crop variety can be vulnerable to weather conditions.

The model predicts that the optimal amount of land allocated to the modern crop variety declines with higher degrees of risk aversion. Hence, the more risk averse a farmer is, the less land is allocated to the modern crop variety (Feder, 1980).

The impact of the farm size combined with risk aversion on adoption of a modern crop variety is analyzed by Feder (1980), through the rate of adoption of a new technology, which is the ratio of land allocated to the modern crop variety to the total farm land available to the farmer. The model by Feder (1980) predicts that the amount of land allocated to a modern crop variety increases with farm size, if the absolute risk aversion is decreasing with farm size. However, the share of the land allocated to the modern crop variety declines with farm size, if the relative risk aversion is increasing.[3] Decreasing absolute risk aversion and increasing relative risk aversion is confirmed in studies by Schulter (1971) and Muthia (1971). Hence, larger farms will have more acres allocated to the modern crop variety than small farms, but larger farms will allocate a smaller share of their land to modern crop variety than small farms (Feder, 1980).

In general, farmers are required to finance the cash outlay for inputs required for modern crop variety, which might be financed by credit (Feder, 1980). In cases where the

[3] In general, if people take more (less) risk when their wealth level increase, then absolute risk aversion is said to be decreasing (increasing) with wealth. Hence, more wealth is allocated to the risky investment. If people show increasing (decreasing) relative risk aversion when their wealth level increases , then they invest less (more) *proportion* of their wealth into the risky investment as their wealth increases (Mas-Colell, *et al*., 1995).

farmer does not have enough savings, the credit constraint can be binding. By assuming that larger farmers can obtain more credit, Feder (1980) shows that when the credit constraint is binding, an increase in the variability of yield will increase the optimal level of input per acre and reduce the land allocated to the modern crop variety. Hence, the farmer tries to decrease the risk by decreasing the amount of land allocated to modern crop variety and increasing the input/crop ratio. However, if there credit is available, then the total acreage of the modern crop variety will increase. Feder (1980) brought an explanation for different adoption rates of new technology by farmers with different farm sizes, through attitude of farmers to risk and uncertainty, farm size and by credit availability.

3.4.4. Fixed costs

Feder and O'Mara (1981) extended the model of Feder (1980) by including fixed costs and incorporating the diffusion of information process. The model analyzes the reduction of yield uncertainty by endogenous and exogenous processes. The endogenous process is the learning-by-doing process; the more acres of land allocated to the new technology, the more information is gained about the yield of the new technology (Feder and O'Mara, 1981). The exogenous process of reduction of uncertainty is provided by agricultural extension services, information provided from outside sources and the research done to reduce the susceptibility of the modern technology (Feder and O'Mara, 1981). This impact is introduced in the model by having a time trend in the uncertainty of the yield.

Feder and O'Mara (1981) conclude that risk aversion is a reason for non-adoption of new technology only to the extent that the adoption incurs fixed costs. The fixed costs may stem from information-acquisition, inefficient credit markets and inefficient input distribution systems (Feder and O'Mara, 1981). Their results also show that larger farmers start adoption of new technology with experimental plots. However, small farmers can only adopt the new technology after larger farmers have obtained the higher yields for some period. Feder and O'Mara (1981) recommend policies that can minimize the information acquisition costs for small farmers and also that can simplify the loan application procedures for small farmers.

The results by Feder and O'Mara (1981) show that the critical landholding size, above which adoption occurs, decreases as the fixed cost of adoption and uncertainty related to yield decreases. This result implies that, over time as more information is gained by endogenous and exogenous processes, the uncertainty will decrease, hence more farms will be able to adopt the new technology.

Just and Zilberman (1983) extend the model of Feder (1980) by allowing both the traditional and new technology be risky and stochastically related to each other. Just and Zilberman (1983) explain the high correlation between two technologies can stem from the modern technology being the improved variety of the traditional technology, so that both crops are susceptible to the same weather conditions and disease. Another assumption of the model is; the adoption of new technology requires fixed costs, which may be due to the purchase of new machinery, investment in time for learning about the technology and the training of labor.

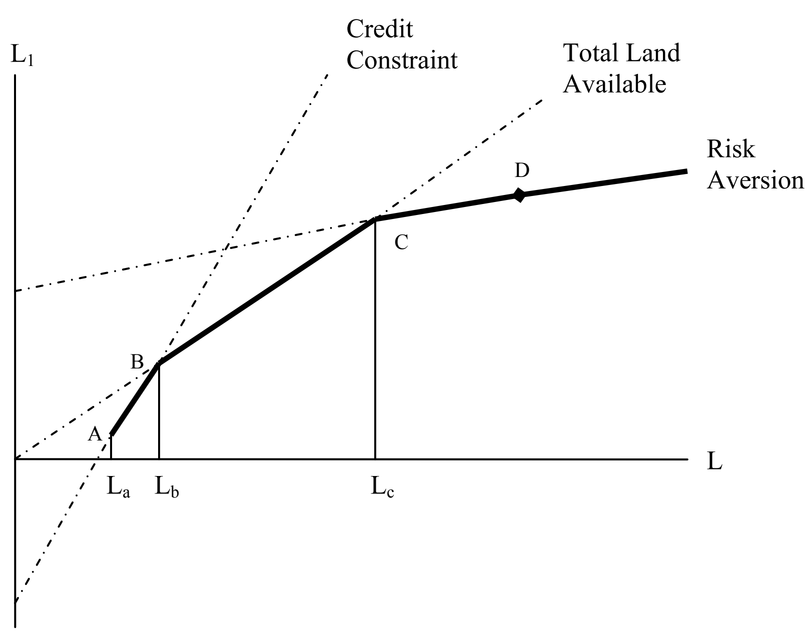
The model obtains the adoption behavior both as functions of attitude towards risk and the correlation between the yield of new and old technologies. The implication of this model is that the findings of the model by Feder (1980) may not be valid under some conditions. Just and Zilberman (1983) show that if yields for both technologies are correlated, farmers may not increase the land allocated to the modern crop even in the case of decreasing absolute risk aversion. Just and Zilberman (1983) also provide conditions under which the share of land devoted to modern technology decreases, when relative risk aversion is either decreasing or increasing in farm size, which confirms and extends the results by Feder (1980). The results of Just and Zilberman (1983) also confirm the results of Feder and O'Mara (1981) that the larger farmers adopt new technologies by first experimenting with them on smaller shares of their land, which are less than the shares devoted by smaller farms. This prediction is consistent with the adoption of some new technologies during the "green revolution" (Feder, *et al*., 1985).

Just and Zilberman (1983) also analyze the impact of fixed cost of adoption of new technology. According to the model, when fixed costs are associated with adoption of new technology and the relative risk aversion is increasing three alternative outcomes of adoption decision can occur. The impact of economies of scale, lower average fixed costs with increasing production, and the correlation between the yields of new and traditional technologies is the reason of different outcomes by Just and Zilberman (1983). The three alternative outcomes are: i) No farms adopt the new technology due to high fixed costs, ii) Farms with size below a critical level do not adopt the new technology, and farms with size above the critical level adopt the technology (this is due to the economies of scale reached by larger farms), iii) In the final outcome farms with sizes in between two critical values adopt the new technology, but farms outside of this interval do not adopt the technology. The farms that adopt the technology do so to reduce the average fixed costs by adopting on more acres, and the non-adopting farms with the largest size don't adopt the new technology due to increasing risk undertaken when adoption of new technology brings higher uncertainty than traditional technology (Just and Zilberman, 1983). The results of Just and Zilberman (1983) show that depending on the size of fixed costs and the correlation between the new and the traditional technologies, large farms can be both adopter and non-adopters of the new technology.

3.4.5. Credit constraint

Just and Zilberman (1988) extends the model of Just and Zilberman (1983) by adding credit constraint into the model. In this model adoption requires both fixed costs and variable costs. Just and Zilberman (1988) defines three limitations to the optimal land allocated to new technology; i) credit constraint ii) risk aversion iii) total land availability. Figure 4 below shows these limitations and the adoption path.

Figure 4: Adoption Path under Credit Constraint (Just and Zilberman, 1988)



Under fixed and variable adoption costs, the credit constraint will be binding and farms with size above a critical point like L_a will start adopting the new technology. The land allocated to new technology will increase until the point *B*, at which point the total land available will be the restricting factor. Hence, the land allocated to new technology will increase with the same amount of total land available between points *B* and *C*. This is the phase of full adoption as $L_1 = L$. At point *C*, the risk aversion factor will be the restricting factor. Hence, farms with size above L_c will increase the land allocated to new technology less than the increase in the farm size. The impact of increasing relative risk aversion will cause large farms to diversify the risk by allocating fewer shares to new technology. Therefore, the adoption path will follow points *ABCD*.

The impact of adoption costs can shift the credit constraint further right, in which case the adoption path will change, and there might be some cases where full adoption never occurs, this is the phase between points *B* and *C* in Figure 4.

3.4.6. Uncertainty and information accumulation

Although the models reviewed in the previous section showed how yield uncertainty can impact the adoption decision, they did not analyze formally the process of information gathering that can impact the yield uncertainty of the new technology. The models that incorporate the information accumulation process formally into the models of technology adoption are reviewed in this section. These models attempt to explain how additional information obtained related to yield uncertainty can impact the adoption decisions of farmers.

Hiebert (1974) analyzes the effects of uncertainty and imperfect information on adoption of fertilizer. The farmers have imperfect information about yield response to the fertilizer and have subjective probability distribution of the yield. The farmers are found to apply less fertilizer and apply on less land due to risk aversion. However, the probability of adoption increases as farmers learn more about the true, objective, probability of yield response. Hence extension efforts and farmers' human capital help information gathering and probability of adoption.

Feder and O'Mara (1982) criticize Hiebert (1974) as not explicitly treating accumulation of information. Hence, they develop an aggregate innovation diffusion model based on the assumption that farmers revise their beliefs about the subjective probability distribution in a Bayesian fashion. Their model shows that the farmers adopt the new technology when their beliefs about the mean value of profits from the new technology is at least as large as the return from the old technology. The model shows that as more and more farmers adopt the new technology, the information about the realized profits are observed by non-adopters, hence the beliefs of the non-adopters are revised.

The models by Hiebert (1974) and Feder and O'Mara (1982) assume that information gathering is passively done by farmers and include no costs. Feder and Slade (1984) extend these models by allowing farmers to intentionally gather information, hence bear a cost of information gathering. According to his model, farmers with higher human capital will be more efficient in information gathering and usage and also larger farmers will have less cost of information gathering. Hence, the model by Feder and Slade (1984) shows that larger farmers and farmers with higher human capital will adopt the new technology earlier.

3.4.6.1. Real options

The development of real options theory or the option value investment rule has been used in finance theory to make investment decisions when there is uncertainty about future profits and also when the investment is irreversible, as an alternative to the net present value rule (Dixit and Pindyck, 1994). Under real options theory, producers may find it rational to wait to make the investment when there is uncertainty about future profit streams, hence to obtain more information about the uncertainty. However, the net present value approach may find it optimal to make the investment, even when the option value approach finds it not optimal to make the investment. Real options theory recently was used to bring explanation to non-adoption of profitable technologies. Some of the studies that applied real options theory to adoption of new technologies by farmers are reviewed next.

Carey and Zilberman (2002) analyze the adoption of water irrigation technologies among farmers in California. According to their study, although modern irrigation technologies have higher expected profit than traditional technologies, the adoption of modern technologies has been low by the Californian farmers. The only explanation from the net present value approach would be that the farmers have extremely high discount rates. By using the option value approach, Carey and Zilberman (2002) show that when there is uncertainty with respect to future prices of water supply, Californian farmers find it optimal to wait for the future, to learn more about the water prices, before they adopt the modern irrigation technologies, which are associated with sunk investment costs. They show that, depending on the distribution of the water price, even if the net present value approach finds it optimal to adopt currently, the option value approach finds it optimal to wait for around 10 years for Californian farmers to adopt the modern irrigation technology. Their analyses also show that, the time to wait to adopt modern technology increases as the fixed cost of investment increases. However, as the efficiency of the modern irrigation technology over traditional technology increases, with respect to water saving, farmers' time to wait to adopt modern technology decreases.

Koundouri, *et al*. (2006) analyze the impact of production uncertainty on the adoption of water irrigation systems by using options value approach to investment. Their results show that the uncertainty with respect to future profits will increase the probability to adopt a technology that decreases the income uncertainty, by saving water. This is similar to the efficiency argument of Carey and Zilberman (2002). Adoption of a technology that reduces income uncertainty is like hedging for risk. Koundouri, *et al*. (2006) found also that, when the effect of technology on future income is uncertain, provision of adoption-related information will increase the adoption of technology, hence decrease the value of waiting. Their regression results show that farmers who consider adopting the new technology are more likely to visit extension services to get more information about the technology. Finally the regression results confirm that, the higher the expected value and the variance of the profit, the greater the probability to adopt the water irrigation technology.

Although models analyzed so far explaned how yield uncertainty and credit constraint impact the adoption decision, they lack other exogenous constraints such as labor constraint, land tenure and endogenous factors such as human capital, which are key elements of agricultural production (Feder, 1980). These additional factors can bring additional constraints to the decision problem, hence lead to different adoption decisions than predicted by previous models. Starting from the next section on, the impacts of these additional factors are reviewed. As shown by the model of Feder and Slade (1984), farmers with higher human capital will adopt new technologies earlier. The next section is devoted to investigating how human capital impacts the technology adoption decision.

3.4.7. Human capital

The human capital approach to adoption of new technology analyzes how education and information contribute to the allocative ability of producers (Huffman, 1974; Wozniak, 1987). The allocative ability is the human's ability to acquire and use information regarding to the production technology (Welch, 1970). Hence, allocative ability is associated with efficient decision making (Huffman, 1974). The introduction of new technology causes disequilibria in the market, in the sense that producers are not making the optimum decisions unless they adjust for the new technology (Schultz, 1972; Huffman, 1974; Wozniak, 1984). A disequilibrium can be not using the optimum level of inputs for the new technology adopted, but rather using the input levels that were optimum for the replaced technology (Huffman, 1974).

Education is assumed to provide skills to augment and use information, hence increasing the allocative ability of individuals (Huffman, 1974; Wozniak, 1984). Hence, it is expected that individuals with higher education will react to disequilibria faster than individuals with less education and adjust the allocation of resources in accordance with the new technology (Huffman, 1974; 1977). The economic loss due to disequilibria causes individuals to search for information to adjust their resource allocation. Hence, the availability of information regarding the new technology also enhances the allocative ability of the individuals (Huffman, 1974; Wozniak, 1984).

Huffman (1977) analyzes how farmers responded to the change in economic conditions due to the introduction of hybrid corn in the Corn Belt during the 1959 to 1964 period. Hybrid corn is more responsive to nitrogen fertilizer than traditional corn. Hence, if farmers do not adjust their usage of the level of nitrogen fertilizer to the optimum level for hybrid corn, there will be disequilibrium due to not using the optimum level of the input in production (Huffman, 1977). The econometric analysis of this study analyzes whether human capital factors impacted farmers' response to change in the nitrogen responsiveness of the crop. The results of this study confirm that farmers with higher education adjust their nitrogen fertilizer usage faster than farmers with less education. The impact on availability of information on farmers' response is represented by the interaction of agricultural extension agents and farmers. The econometric results show that as the contact between agricultural extension agents and farmers increases, farmers adjust their nitrogen usage faster (Huffman, 1977).

Wozniak (1984) redefines allocative ability as innovative ability and applies it to adoption of new technology. Wozniak (1984) defines innovative ability as the capacity to be productive with new technology and the ability to search for and evaluate information efficiently in making innovative decisions. As with allocative ability, education helps individuals acquire knowledge and skills that are required to be productive with the new technology (Wozniak, 1984). Education also helps individuals to better evaluate the economic benefits and costs of adopting a new technology (Wozniak, 1984). Experience is also assumed to have the same impact as education on innovative ability. Each work activity will enhance the skills of an individual, which will contribute to making efficient adoption decisions (Wozniak, 1984). Finally, due to imperfect information related to the performance of the new technology, information related to the new technology also enhances the efficiency of the adoption decision (Wozniak, 1984). Overall, Wozniak (1984) hypothesized that, education, experience and information enhance the innovative ability of individuals and lead to efficient adoption decisions.

To test these hypothesis, Wozniak (1984) analyzes adoption of a livestock feed additive, monensin sodium, which increases the feed efficiency, among Iowa farmers in 1976. The results confirm that a farmer’s probability to adopt monensin sodium increases with the level of education and interaction with extension service. However, the results do not support the hypothesis that farmers with more experience are more likely to adopt the new technology. Wozniak (1984) explains the insignificance of experience with the fact that younger farmers, who have less experience, have longer streams of benefits from adopting the new technology and this effect outweighs the uncertainty effect on which experience is effective.

Rahm and Huffman (1984) define the efficiency of adoption decision as; adopting the practice when it is economically feasible and not adopting when it is economically not feasible. Hence, human capital may not always be associated with higher adoption rates, but with higher adoption rates when it is feasible to adopt. Rahm and Huffman (1984) analyze the impact of human capital variables on adoption of reduced tillage and the efficiency of the adoption decision. The regression results of their study show that farmers with more years of formal schooling are more likely to make efficient adoption decisions.

Most of the studies on adoption of new technology found that the probability of adopting the new technology is increasing with human capital. The results of Abdulai and

Huffman (2005) show that as the number of previous adopters increases, the diffusion of profitable cross-breeding technology is enhanced, due to farmers learning from others. Their results also show that as the number of years of schooling of the farmer increases, the faster the adoption happens. The results of Abdulai and Huffman (2005) also show that the extension services also speed the diffusion of new technology. Chang and Boisvert (2005) found that probability to participate in CRP increases with farmers' education level. Authors attribute this result to the increase in farmers' appreciation of environmental benefits of CRP. Barham, *et al*. (2004) found that farmers with higher education levels are more likely to adopt rBST. Koundouri, *et al*. (2006) found that farmers' education and interaction with agricultural extension services increase the probability of adoption of new irrigation technology. Qaim and de Janvry (2003) found that farmers who have contact with private sources of information, such as private companies, merchants and other private agents are more likely to adopt Bt Cotton than farmers whose only source of information is neighbors and unofficial sources for new information. Their results also show that as the number of years in school increases, the farmers become more likely to adopt Bt Cotton. Khanna (2001) found that adoption of variable rate application technology is impacted positively and significantly by the education, innovativeness and experience of the farmer. As the adoption of variable rate technology happens after adoption of soil testing, farmers with higher human capital can get better use of the results of the soil testing (Khanna, 2001). Hua, *et al*. (2004) found that farmers with college education are more likely to adopt conservation tillage.

Some of the studies that did not find a significant relationship between human capital and adoption of new technology are reviewed next. Upadhyay, *et. al*. (2002)

found that the impact of the highest level of education be positive but insignificant on adoption of no-tillage and continuous spring cropping. Soule, *et al*. (2000) found that the coefficient on college education is negative and not significant for the practices with benefits occurred in the long run. Khanna (2001) found that adoption of soil testing is not affected by the education, innovativeness and experience of the farmer. Upadhyay, *et. al*. (2002) found that the highest level of education is not statistically different between adopters of a single practice and zero practice adopters. Hua, *et al*. (2004) found no significant relation between education and participation in a conservation program. Qaim and de Janvry (2003) found that public sources of information, which consist of agricultural extension and cooperatives,s were found to have positive but insignificant impacts on adoption of Bt Cotton.

3.4.8. Age

Age is also included in analyses of adoption of new technology to represent the experience and innovativeness of the farmer, which are mentioned in the human capital theory, and also to capture the discount rate differences of future income between younger and older farmers. The empirical results show both positive and negative relationships between age and adoption of new technology. Upadhyay, *et. al*. (2002) found a positive but insignificant relationship between age and adoption of no-tillage and a negative and insignificant relationship between age and adoption of continuous spring cropping. Chang and Boisvert (2005) found that as the farmers get older, they become more likely to participate in CRP. Chang and Boisvert (2005) attribute this result to farmers' willingness to reduce their labor requirements or holding onto the farmland assets until they are required during the retirement years.

Soule, *et al*. (2000) found that age had a negative and significant impact on adoption of practices for medium and short term benefit practices for owners but not for renters. Qaim and de Janvry (2003) found that age has no impact on adoption of Bt Cotton. Barham, *et al*. (2004) found that younger farmers are more likely to adopt rBST. Hua, *et al*. (2004) found no significant relation between age and participation in a conservation program. Hua, *et al*. (2004) also found that farmers younger than 60 years old are more likely to adopt conservation tillage.

3.4.9. Off-farm income

Off-farm work has become a significant source of income for farm families (Mishra, *et al.*, 2002). Mishra, *et al*. (2002) report that, in the U.S., 71 percent of farm households had either the operator, spouse or both have off-farm work in 2002. According to Mishra, *et al*. (2002) total net U.S. farm household income earned from farm activities increased from $15 billion in 1969 to $50 billion in 1999. Whereas, the farm household income earned from off-farm activities increased roughly from $15 billion in 1969 to $120 billion in 1999. Hence, the share of off-farm income in farm household income rose from roughly 50% in 1969 to 90% in 1999 (Mishra, *et al.*, 2002). The convention was that the off-farm work was a temporary source of income. However, Ahearn and El-Osta (1993) showed that farm families continue to have off-farm income throughout the year. Therefore, off-farm work permanently exists in the life of farm households. There is a positive correlation between off-farm work and income variability (Mishra and Goodwin, 1997). Hence, risk averse farmers use off-farm work to avoid the income variability due to risk associated with farm income (Huffman, 1980; Barlett, 1986; Mishra, *et al.*, 2002).

Given the importance of off-farm work to farm households, off-farm income has been recently added to the analysis of technology adoption. The current studies can be analyzed in two groups. Some of the studies analyze the joint decision making of off-farm work participation and adoption of a new technology and test whether these two decisions are done simultaneously, sequentially or independently. Other studies analyze how having off-farm work impacts the adoption of new technology by incorporating off-farm work as an explanatory variable into the econometric analysis of adoption of new technology. The theory of off-farm income supply and the results of the previous studies are reviewed next.

The theory of off-farm labor supply is based on the seminal study by Huffman (1980). Huffman (1980) provides a utility maximization model that explains how farmers make decisions to work off the farm and on the farm simultaneously. The model shows that when farmers allocate their time, they choose levels of off-farm work, on farm work and leisure such that, the marginal values of the farmer's time at off-farm work, on-farm work and leisure are equal. The model also predicts that education and agricultural extension services may affect the off-farm work decision through making the agricultural production more efficient and saving more time for off-farm work.

The econometric results of Huffman (1980) show that off-farm work participation increases with the level of education, intensity of extension services and variability of farm sales. Education had led farmers to reallocate their time from on-farm work to off-farm work faster than farmers with less education; hence education increased the allocative ability of the farmers (Huffman, 1980). The size of the farm production is found to negatively impact off-farm participation due to time restriction, but the variability of farm sales increases the participation in off-farm work due to risk aversion of the farmers (Huffman, 1980). Recent studies by Goodwin and Bruer (2003) and Bharadwaj and Findeis (2003) found similar results.

Besides the increasing importance of off-farm work to farm households, the contribution of women to farm household income through off-farm work activities has also increased (Hallberg, *et al*., 1991; Tokle and Huffman, 1991, Mishra, *et al*., 2002).The decision to work off the farm has been shown to be a joint decision between the husband and the wife (Huffman, 1989; Tokle and Huffman, 1991). Huffman (1989) provides a theoretical model to examine the off-farm decisions of the husband and wife jointly. Hence, the farm household has decision variables to have off-farm work separately both for the husband and the wife. The econometric analyses of this study involved estimation of off-farm labor supply for the husband and wife separately. The main finding of this study is that the estimates of the explanatory variables are significantly different for husband and wife. Hence, the studies that do not account for the differences in off-farm work participation of husband and wife will have serious specification errors (Huffman, 1989).

The studies that analyze how adoption of new technology is impacted by off-farm work found different results due to differences in the technologies being adopted. The study by Cornejo, *et. al*. (2005) found that adoption of herbicide-tolerant soybeans is positively and significantly affected by the farmers' off-farm work. The authors argue that the adoption of herbicide-tolerant soybeans could be due to the time saving nature of this technology, which provides opportunity for farmers to work off the farm. Upadhyay, *et. al*. (2002) found that the amount of off-farm income has a positive but insignificant impact on the adoption of no-tillage and continuous spring cropping. Upadhyay, *et. al*. (2002) attributes the positive sign to the contribution of off-farm income to the financial resources. However, the insignificance is attributed to the lack of off-farm employment opportunities in the study area. According to the study by Chang and Boisvert (2005), farmers who have off-farm work are more likely to participate in CRP. Farmers who have off-farm work might participate in CRP to reduce operator labor requirement (Chang and Boisvert, 2005). Hua, *et al*. (2004) found a negative and significant relationship between off-farm work and participation in a conservation program. The authors attribute this relation to opportunity cost of time that is required for transactions to participate in a conservation program and also the off-farm work would indicate the need for the additional income, in which case participation in a conservation program would increase the need for additional income, as these programs only provide partial funding for adoption costs. However, impact of off-farm work is found to be insignificant on adoption on conservation tillage.

3.4.10. Miscellaneous factors

Some of the important miscellaneous factors that are analyzed in adoption studies, which are also important for the current study, are reviewed in this section.

3.4.10.1. Tenure

Land tenure has been found to be an important factor in adoption of new technology (Feder, *et. al*., 1985). However, a clear relationship between tenure and adoption is not found in previous studies (Feder, *et al*., 1985). The paper by Soule, *et al*. (2000) provides a behavioral model that distinguishes the incentives between land owners and renters. This paper and some empirical results are reviewed in this section.

Soule, *et al*. (2000) analyze the impact of tenure on adoption of soil conservation practices. They distinguish the practices in terms of the timing of the benefits. Conservation tillage is used as a practice for which benefits are observed in the short term, grassed waterways, strip cropping and contour farming are used as practices with benefits observed in the long term. Soule, *et al*. (2000) distinguish rental arrangements with share-renters from rental arrangements with cash-renters. Share-renters share the cost and revenue of the production with the owner. On the other hand, cash-renters lease the land from the owner; hence bear all costs and benefits related to the production. Their econometric results show that, when share-renters and cash-renters are not distinguished from each other, the impact of tenure on adoption is negative but insignificant for the practice with short term benefits. However, when the renters are distinguished as share and cash-renters, the results show that cash-renters are significantly less likely to adopt than the owner-operators. However there is no significant difference between share-renters and owner-operators. For the practices for which benefits are observed in the long-term, the regression results reveal both share and cash-renters are significantly less likely to adopt the practice. Their results show that the impact of tenure on adoption will differ depending on the timing of benefits from adoption and type of tenure arrangement. Soule, *et al*. (2000) mention the ability of owners to require renters to use specific practices or inputs will also impact the adoption and requires further research.

Empirical studies that incorporate tenure into the analysis of adoption of new technology found different results. The study by Rahm and Huffman (1984) found a positive but insignificant effect of land rented-in on adoption. Upadhyay, *et. al*. (2002)

found that the percent of land rented in has a negative but insignificant impact on the adoption of no-tillage and continuous spring cropping. Upadhyay, *et. al*. (2002) attributes this result to the shorter time horizon of renters for the benefits of soil conservation practices. Hua, *et al*. (2004) found a positive and significant relationship between the proportion of total acres owned and participation in a conservation program. As the renters don't have an incentive to maintain the soil fertility and control erosion, they are less likely to participate in a conservation program (Hua, *et a*l., 2004). However, a negative and significant relationship is found between acres owned and adoption of conservation tillage (Hua, *et al*., 2004).

3.4.10.2. Perceptions

Perceptions of farmers about the environmental problem and the technology to be adopted have been incorporated into adoption of conservation studies to measure the impact of environmental awareness and stewardship of farmers on adoption of conservation practices by farmers. Although perceptions are included in the empirical models, they have not been included in the behavioral models of adoption in the Bayesian equilibrium fashion. Some of the empirical results of previous studies follow.

Upadhyay, *et. al*. (2002) found a negative but insignificant relationship between the perception about soil erosion and adoption of soil conservation practices. The authors cite Carry and Wilkinson (1997) and mention that environmental perceptions will not result in action unless there are economic or other benefits.

Hua, *et al*. (2004) found a positive and significant relationship between perceptions about the impact of agriculture on water pollution and participation in a conservation program. According to this study also, farmers who believe that the government should regulate farming practices to improve the water quality are more likely to participate in a conservation program. However, perceptions about soil erosion were not found to be significantly impacting participation in a conservation program. Hua, *et al*. (2004) also found a negative but insignificant relationship between adoption of conservation tillage and expected transfer of the farm to children upon retirement. Their results also show that farmers' who believe erosion is a problem in Ohio are more likely to adopt conservation tillage, but there is no significant relation between erosion being a problem on the farmer's own farm. The impact of social norms is also found to be insignificant. Hence, there is no evidence that farmers adopt conservation tillage with the consideration of other peoples' opinions.

3.4.10.3 Multiple practice adoption

The heterogeneity between a single practice adopter and a multiple practice adopter and how this heterogeneity impacts adoption of technology is analyzed by Upadhyay, *et. al*. (2002). Upadhyay, *et. al*., (2002) analyze the adoption of multiple conservation practices in Washington, which are reduced tillage, continuous strip cropping and vegetative wind strips. Upadhyay, *et. al*. (2002) assessed the ability of farm and farmer characteristics to predict the difference between adopters and non-adopters when non-adopters are defined as the farmers that do not adopt the specific practice versus farmers who do not adopt any of the practices, zero practice adopters. Their t-statistic results show that, the farm is not significantly different between single practice adopters and zero practice adopters. However, multiple practice adopters have higher farm size than zero practice adopters, which is statistically significant at an $\alpha = 0.04$ level. The results of Upadhyay, *et. al*. (2002) for the logistic regressions for both adoption of no-tillage and continuous spring cropping show that, the coefficient of farm size is positive and significant when non-adopters are defined as zero-adopters. However, the coefficient of farm size becomes insignificant and less significant for continuous spring cropping and no-tillage, respectively, when non-adopters are defined as non-adopters of the specific technology.

3.4.11. Multivariate probit regression

The previous studies that analyzed the impact off-farm income and adoption of multiple practices revealed the importance of separating off-farm work decisions of the farm operator and the spouse and using either bivariate or multivariate probit regression models. Most of the empirical studies focus on either adoption of an individual practice within a multi-component technology package or adoption of the package as a whole (Khanna, 2001; Dorfman, 1996). The studies that analyze individual practices within a package, treat adoption of each practice as independent. The single equation estimation of adoption of individual practices within a package ignores the correlation among the adoption of inter-related practices (Khanna, 2001; Wozniak, 1984). The correlation might arise from either unobserved factors, which might impact the adoption of all the practices in the package, or the adoption of one practice may be conditional on adoption of another practice (Khanna, 2001; Dorfman, 1996). Khanna (2001) explains that when adoption decisions of inter-related technologies are modeled as independent single equations, the estimates for these single equations will be inefficient; hence the variance of the estimated coefficients will be large. For this reason bivariate or multivariate regressions should be used depending on the number of inter-related technologies. These regression models will be explained in detail in chapter 4.

3.5. Contribution of the Current Study

There is a voluminous literature on adoption of agricultural practices and technologies. Profitability was one of the earliest factors studied and one which fairly consistently has a positive effect in the empirical literature. Even this factor however is affected by other factors such as credit constraints, uncertainty, human capital, off-farm income and others. Early studies focused on diffusion of a new technology, the adoption rate of the new technology by potential adopters, as it was expected that a profitable technology would be adopted. However, as the new technology was not adopted by all potential adopters, factors other than profitability were investigated to explain why farmers did not adopt the new technology. This led the search for the heterogeneity among farmers and which led the start of adoption studies.

The adoption literature shows that the specific characteristics of the practice interact with characteristics of the farm and the farmer so adoption decisions can be quite difficult to predict, especially for environmental practices. This caused studies or theories to explain rather a small portion of the adoption decision rather than the whole process. It is expected that as studies continue to analyze the adoption process of a new technology, more factors will be discovered to impact adoption and hopefully studies will provide the rational why these new factors are impacting the adoption process. As the adoption of new practices / technologies is impacted from the characteristics of the practice / technology, farmer and farm, as these characteristics change over time, number of factors that impact the adoption process will increase.

Some of the studies provided economic models to explain the impact of a certain variable, such as farm size or human capital, on the adoption decision, whereas other studies searched for statistically significant evidence on which factors or variables impact adoption of new technologies or practices. The results of these studies show there are a variety of factors impacting the adoption decision of farmers. However, a difficulty arises for researchers since the impact of a certain variable can change from one study to another. This raises the issue that we need economic models or other models to understand and predict how a certain variable impacts the adoption decision. Off-farm income is a factor like this.

The empirical results of previous studies showed that the off-farm income level of farmers has a significant impact on their decision to adopt new technologies. However, the way off-farm income is affecting the adoption decision is not clear. What does having off-farm income imply? Do the farmers with off-farm income have more financial resources or do they have less time available for farm work or are they more educated and more concerned about the environment? We need to know what having off-farm income implies to better understand and predict its impact on adoption of new technologies or practices.

One of the contributions of the current study will be to provide a behavioral model that represents the impact of off-farm income on adoption of new technologies or practices by providing the conditions that show when capital intensive and management intensive technologies have higher chances of being adopted when farmers have off-farm work. There can be two effects; 1) farmers with off-farm income have more financial ability to adopt new technologies, 2) farmers with off-farm income don’t have enough time to adopt new technologies. Hence, depending on capital and time requirements of the technology or the practice, the off-farm income can be a factor that intensifies the adoption or a factor that defers the adoption.

The first studies that analyzed adoption of new technologies by farmers focused on only profit oriented practices. Also, studies that analyzed the impact of farm size or human capital also focused on adoption of profit oriented practices during the "green revolution". This might be understandable for that period since the big issue was to convince farmers to adopt technologies that will increase their production. However, these days the focus of policy makers and the public is not only on agricultural production but also environmental quality. Hence, policy makers want to learn which factors impact adoption of technologies or practices that improve environmental quality. When a researcher analyzes the factors that impact adoption of a technology that benefits the environment, it is normal to look at previous studies that analyzed adoption of technologies by farmers and use the intuition from those studies, such as the studies that analyzed the impact of farm size during the "green revolution". However, a problem may arise if the characteristics of practices differ which might cause factors affecting adoption to differ.

The empirical studies reviewed so far had either analyzed profitable practices or environment-oriented practices, but not both. Even the studies on multiple practice adoption had all the practices only environment-oriented. The contradictory results of the empirical studies show that both farmer and farm characteristics impact adoption in different ways depending on the attributes of the new technology. To better represent how different variables impact adoption of different technologies, analysis of both environment-oriented and profit-oriented technologies should be done jointly. For this reason, the current study incorporated both environment-oriented and profit-oriented technologies into the analysis. The contribution of the current study will be to show how attributes of the new technology or practice can change the impact of the variables, which were reviewed in the literature. If evidence can be found that adoption of environment-oriented and profit-oriented practices is impacted by different factors, this can lead to new studies that try to explain how certain factors can impact practices that aim at increasing environmental quality. This would then allow policy makers to make more efficient policies to increase environmental quality.

3.6. Specific Hypotheses

The literature review allows us to synthesize previous work and to help develop specific hypotheses regarding the expected effect of a number of variables:

Age: Age can impact adoption both positively and negatively. Experience is expected to make the farmer more capable and allocatively efficient, hence increasing adoption of practices. Younger farmers have longer streams of benefits from adopting the technology, hence increased age decreases adoption.

Iowa vs. Missouri: Farmers in Iowa are expected to be more likely to adopt practices that are suitable for crop farmers than farmers in Missouri since they have crop-intensive production.

Education: Farmers with higher education are expected to be more likely to adopt new practices and they have more skills and information to be successful.

Off-Farm Income / Work: Farmers with off-farm income are more likely to adopt capital intensive practices and less likely to adopt time intensive practices.

Contributes Significantly to Farm Work: Farmers with a spouse or another family member contributing significantly to farm work are expected to be more likely to adopt practices, due to extra labor that is available.

Off-Farm Work Interferes with Farm Work: Farmers with off-farm work that interferes with farm work are less likely to adopt practices that are time intensive.

Hire Non-Farm Labor: Farmers that hire non-farm labor are expected to be more likely to adopt practices, due to the extra labor that is available.

Farm Sales: Larger farms are expected to be more likely to adopt practices than small farms. However, risk aversion can cause larger farms not to adopt a practice and one expects no relationship between farm size and adoption if the practice is scale neutral.

Perceptions about the Environment: It is expected that farmers with positive environmental perceptions will be more likely to adopt practices that are beneficial for the environment. It is expected that environmental perceptions would not impact the adoption of solely profit oriented practices.

Continue Farming: Farmers that will continue farming in the next 5 years are expected to be more likely to adopt practices that have streams of benefits in the long term.

Expand Livestock Numbers: Farmers that will expand livestock numbers in the next 5 years are expected to be more likely to adopt practices that have streams of benefits in the long term.

Perceptions about Practices: Perceptions of profitability and improving water quality are expected to increase adoption. Being time consuming and complicated are expected to decrease adoption.

Environmental Quality Incentives Program (EQIP): Since EQIP is a cost-share program to benefit the environment, farmers that have an EQIP contract are expected to be more likely to adopt practices that are beneficial for environmental quality.

Manure Handling System: Type of manure handling system is expected to impact the adoption of practices, since the manure handling system will determine which practices are suitable for a farmer (e.g. farmers with only solid manure handling systems can not adopt injecting manure since it requires liquid manure).

Total Animal Units: As the number of animal units increases, there will be more manure to be handled by the farmer. It is expected that number of animal units / amount of manure to be handled to impact the adoption of practices in much the same way as size of farm.

Species: Livestock specie will impact the type of manure handling and also the farming system (e.g. AU/land ratio). Therefore, it is expected that livestock specie impacts adoption of practices.

CHAPTER 4: METHODS AND PROCEDURES

4.1. Data

A mail survey of 3014 farmers, including both CAFOs and AFOs, was conducted in Iowa and Missouri in spring 2006.[4] Before random sampling, farmers were stratified by farm sales and by type of livestock. Farmers with farm sales less than $10,000 were not sampled. This eliminates most retirement / lifestyle farmers (Hoppe and Banker, 2006). In designing the survey, the methodology discussed by Dillman (2000) was followed. Dillman (2000) was also used in conducting the survey to increase the response rate. The questions were designed to learn whether farmers have adopted the selected conservation practices and how the farmer's and the farm's characteristics impacted the adoption decision. The survey was sent out to a test group of 100 farmers and was revised before developing the final survey instrument. The final survey was sent out with a cover letter, a postage paid return envelope and also a form to participate in a $200 gift certificate drawing. A reminder postcard was sent, followed two weeks later by a second wave of the complete package, again asking farmers to participate. The effective response rate for the survey was 37.4 percent. Before calculating the response rate, the farmers that had stopped farming as well as undeliverable surveys were subtracted from the original number of surveys that were sent out. The effective rate is the number of returned surveys divided by the adjusted number of surveys sent, times 100.

Imputation is a widely used method to overcome missing values for large data sets (Huisman, 2000). The study by Horton and Kleinman (2007) shows that imputation improves the efficiency and reduces the bias of estimates. Horton and Kleinman (2007)

[4] The full version of the survey is presented in appendix A.

recommend the use of imputation techniques when there are missing values. Using a data set with many variables in the regression analyses require that the data set does not have many missing values. For any observation, if there is even one missing value for a variable, the values for other variables also can not be used for that observation. This loss of data creates the inefficiency and bias problems of the estimates discussed by Horton and Kleinman (2007). If there are systematic differences between respondents and non-respondents, imputation can cause biased estimates (Huisman, 2000). Therefore, care should be given to selection of the variables that will be imputed. Imputation has also been used for the National Health and Nutrition Examination Survey (NHANES) since 1996 (NHANES III, 2001).

For the regression analysis, CAFOs are excluded from the data set to focus on factors affecting voluntary adoption. Farmers with no land were also removed from the data set since many of the practices related to land application. Only for the regression of Roundup Ready soybeans, farmers with no soybean production were also dropped from the dataset, as adopting Roundup Ready soybeans is relevant only farmers with soybean production. For imputation, farmers with more than 10 percent of the variables missing were also removed from the data set (Musil *et al.*, 2002). Hence, the cut-point was 8 variables and above. Overall, 92 observations were dropped for this reason. Finally, farmers who answered the same number for all perceptions for all practices are also removed from the data set, as their answers were not credible. There were 5 farmers that answered the same number, which was 3, to all perceptions for all practices. Hence, these farmers are removed from the data set. The Likert scale variables turned in three dummies. Responses 1 and 2 are combined and converted into one dummy, response 3 converted in to another dummy, and 4 and 5 are combines and converted into another dummy variables. In the regressions, the dummy created by combing 4 and 5 is used as the base group due to computational difficulty when other groups are used as the base category.

Stata software has been recommended for analyzing survey data (Mitchell, 2006). Stata can handle a wider variety of survey designs, such as stratification and clustering, than SAS or SPSS (Mitchell, 2006). Stata can, for example, run multinomial probit regression taking into account stratified survey data. The missing observations were imputed using the Stata software command "impute". For any variable to be imputed, a regression with a set of explanatory variables is required. In Stata software the number of explanatory variables for an imputation regression is limited to around 10 variables. The regression results then are used to predict the missing values for the dependent variable of the imputation regression.

The following explains the details of the imputation process that is followed by the Stata software. This procedure is based on the manual for Stata 9 (StataCorp., 2005). Assume that for any observation there are $x_{i1}, x_{i2},..., x_{ik}$ variables and $i = 1,2,...,n$ observations in the data set. If the variable x_k is going to be imputed, $x_1, x_2,..., x_j$ variables are selected from the data set for which $j \approx 10$ and $j \neq k$. Using the observations for which there are no missing values for variables $x_1, x_2,..., x_j$ and x_k, x_k is regressed on $x_1, x_2,..., x_j$ using the OLS procedure.

This regression can be represented as;

$$x_k = \beta_0 + \beta_1 x_1 + \beta_2 x_2 +,...,+ \beta_j x_j + U$$

where the βs are the coefficients that are going to be estimated and U is the error term. Once the β coefficients are estimated, x_k can be written as;

$$x_k = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 +,...,+ \hat{\beta}_j x_j$$

where the $\hat{\beta}$s are the estimates of the β coefficients. For any observation for which x_k is missing, x_k can be predicted by plugging in the values for $x_1, x_2,..., x_j$ for that observation into the equation above.

As mentioned above, the regression used for imputation is an OLS regression. This makes the procedure more difficult for a variable that is Likert-scale. As the prediction for a Likert-scale variable from an OLS regression can be a non-integer number, these predictions then had to be turned into the closest integer. For example, when the variable "smell of manure bothers my neighbors" (which is a Likert-scale variable between 1 and 5) was imputed some of the imputed values were non-inters such as 1.2. The imputed values between 1 and 1.5 were turned into 1, the ones greater than 1.5 and smaller than 2.5 were turned into 2, and this procedure followed until the integer 5. A similar procedure was applied for categorical variables such as off-farm income.

To see the impact of imputation on the variables, pre and post imputation values of the mean and the standard deviation of the variables were compared. It was seen that imputation did not cause the mean and the standard deviation to change materially. This shows that there was not a big change in the distribution of the variable caused by inserting the imputed values, yet the number of observations was significantly increased for the regression analysis. An almost 50 percent increase in the number of observations used in the regression analysis was accomplished by using the imputation procedure. The increase in the number of observations also helped the simulation based estimation for multivariate probit regression to be accomplished. A check of whether the change in the independent variables for the imputation regression was causing the imputed values to change materially was also done. It was seen that the change in the independent variables for imputation regression did not impact the imputed values materially.

4.2. Probit and Multivariate Probit Regression Models

For the case of a single technology, the factors that impact adoption of the technology can be analyzed using univariate probit and logit models. In this case the probability of adopting the technology, conditional on the explanatory variables, can be represented as;

$$P(y = 1 | x_1, x_2, ..., x_k) = G(XB)$$

Where $x_1, x_2, ..., x_k$ are *k* explanatory variables and G(.) is the cumulative distribution function. In case of the probit model, the standard normal distribution function is used for G(.) and for the logit model the logistic cumulative distribution function used for G(.) (Greene, 2003).

The bivariate probit model is reviewed briefly to clearly show the difference in the structure between the univariate model described above and the multivariate probit model.

Following Greene (2003), for the case of adoption of two technologies;

$y_1 = X_1\beta_1 + \varepsilon_1, \quad y_1 = 1$ if technology 1 is adopted, 0 otherwise,

$y_2 = X_2\beta_2 + \varepsilon_2, \quad y_2 = 1$ if technology 2 is adopted, 0 otherwise,

$\mathrm{E}[\varepsilon_1 | X_1, X_2] = \mathrm{E}[\varepsilon_2 | X_1, X_2] = 0,$

$Var[\varepsilon_1 | X_1, X_2] = \mathrm{Var}[\varepsilon_2 | X_1, X_2] = 1,$

$Cov[\varepsilon_1, \varepsilon_2 | X_1, X_2] = \rho$

The errors are assumed to have a bivariate normal distribution with expected values equal to zero and variances equal to one. The correlation between adoption of the two technologies is represented by ρ, the covariance between the error terms. If ρ is found to be significant, its sign shows the direction of the correlation (Greene, 2003; Khanna, 2001). The multivariate probit model is the extension of the bivariate model mentioned above by adding more equations and assuming the error terms have a multivariate normal distribution. The multivariate probit model for 4 technologies can be represented as;

$y_1 = X_1\beta_1 + \varepsilon_1, \quad y_1 = 1$ if technology 1 is adopted, 0 otherwise,

$y_2 = X_2\beta_2 + \varepsilon_2, \quad y_2 = 1$ if technology 2 is adopted, 0 otherwise,

$y_3 = X_3\beta_3 + \varepsilon_3, \quad y_3 = 1$ if technology 3 is adopted, 0 otherwise,

$y_4 = X_4\beta_4 + \varepsilon_4, \quad y_4 = 1$ if technology 4 is adopted, 0 otherwise.

CHAPTER 5: SUMMARY STATISTICS

Policy makers and scientists need good data on farmer practices and perceptions to guide policy and research decisions rather than relying on anecdotal evidence. In this chapter, the summary statistics from the survey data will be presented. The discussion will begin with data on the response rates for the survey, followed by descriptive statistics for the variables of interest. The data regarding environmental perceptions, farm sales, off-farm income and off-farm work, environmental perceptions versus off-farm income, manure handling systems and cropped land, perceptions and adoption rate of practices, and the influence of different organizations on farm decision-making are then examined in more detail. Some recommendations for extension and educational programs based on this data are then made.

5.1. Response Rates for the Survey

Table 1 shows the response rates for the survey, which is stratified by state, livestock specie and farm sales. The database from the United States Department of Agriculture was used for the survey sampling and stratification could only be done by farm sales and not by animal units. As mentioned previously, to avoid hobby farms, farms with less than $10,000 in sales were not sampled. In Table 1, for each state, columns show the type of the livestock operation and rows show the farm sales category. For example for Iowa, out of the beef producers with farm sales between $10,000 and $99,999 to whom the survey was sent, 32.2 percent of them returned the survey. The overall effective response rate for the survey, after correcting for undeliverable surveys and people who no longer have livestock, is 37.4 percent.

For Iowa, swine and beef producers seem to have higher response rates than dairy, broiler and turkey producers. Turkey producers have the lowest response rates except for the largest farm sales category. In general for Iowa, there is no trend for response rates with respect to farm sales, except for turkey producers. For Missouri, smaller farms tend to have higher response rates than larger farms. Beef, swine and dairy producers in Missouri have lower response rates than the ones in Iowa. For broiler and turkey producers, there is no clear pattern for Iowa versus Missouri farmers.

Table 1: Response Rates for the Survey

IOWA

Farm Sale	Beef	Swine	Dairy	Broiler	Turkey
$10,000-$99,999	32.2%	29.1%	20.2%	5.3%	0.0%
$100,000-$249,999	46.4%	49.1%	17.5%	33.3%	10.0%
$250,000-$499,999	24.6%	31.0%	24.8%	100.0%	15.8%
$500,000 +	24.6%	35.1%	18.6%	9.5%	30.0%

MISSOURI

Farm Sale	Beef	Swine	Dairy	Broiler	Turkey
$10,000-$99,999	23.6%	12.7%	14.0%	21.6%	70.2%
$100,000-$249,999	15.1%	26.3%	33.3%	46.5%	26.2%
$250,000-$499,999	9.0%	9.7%	15.0%	21.8%	7.9%
$500,000 +	10.4%	5.3%	7.1%	1.1%	3.3%

5.2. Descriptive Statistics

Table 2 gives the general descriptive statistics for the survey data. Some of the variables are analyzed further later in the chapter. The average age of farmers in the survey was 51. As younger farmers are associated with innovativeness, the younger average age can imply higher adoption rate of practices. Fifty one percent of the survey respondents were from Iowa and the rest were from Missouri, which shows almost even representation of the states. As for educational attainment, the most common category was a high school degree. There were more farmers that have an education level higher than high school than have less than high school. In the literature, higher education level is associated with higher adoption rates and also higher possibility of off-farm income. For farm sales, which includes both crop and livestock sales, the most common category was between $100,000 and $249,999. If we call this category mid-size farms and the farms with farm sales less than this category small-size farms, and the farms with farm sales higher than this category large-size farms, we have very similar numbers of small, mid and large-size farms in the survey data. As the adoption behavior of farms varies with farm sales, having representation of farms with different sales levels is important.

A majority of the farmers indicated that they or a family member expect to continue farming their current farm in the next 5 years. This can increase their probability of adopting nutrient management plans since any initial learning costs or investments will be spread over a longer time period. Almost 30 percent of the farmers indicated that they expect to increase their livestock numbers in the next 5 years, which shows that excess manure relative to crop needs may increase in the future, and worsen manure management problems. Only 18 percent of the farmers had an Environmental Quality

Incentives Program (EQIP) contract through the Natural Resources Conservation Service. As EQIP is a cost share program to provide incentives for farmers to adopt better management practices, including nutrient management practices.

Seventy percent of respondents had off-farm income, which is similar to the national average of 71 percent as reported by Mishra, *et al*. (2002) for all farms. About 14 percent of the farm operators had seasonal off-farm work and 22 percent had year round off-farm work so most farmers do not have off-farm jobs. These numbers are 7 percent and 50 percent for the spouse, respectively so the majority of spouses have off-farm work. The operator and their spouse are more likely to hold a year round off-farm job rather than working seasonally. Livestock production occurs year round and is relatively labor intensive, however, only 19 percent of the survey respondents indicated that off-farm work interferes with the timing of their farming operations, while 50 percent answered no and the rest indicated that the question was not applicable to them. Farmers who indicated that off-farm work doesn't interfere with the timing of farming operations may be the farmers that hire non-family labor or other family members might be helping with the farming operation. It may also be that their farming operations are more flexible. About 48 percent of the farmers hired non-family labor in 2005.

On 57 percent of the farms, the spouse of the farm operator significantly contributed to farm work and in 41 percent of the farms another family member contributed significantly to farm work. Unlike the expectation that if the spouse has year round off-farm work, they would not be contributing significantly to farm work, the 57 percentage shows that at least 7 percent of the spouses who have year round work also contribute significantly to farm work. As far as the type of livestock operation, the most common group is swine with 27 percent of the farms. Overall, none of the types of operations seems to be over sampled. As manure management systems vary with the type of the operation, an over sampling of a specific type of livestock operation would mean a bias towards adoption of specific nutrient management practices.

In the survey, the overall adoption rate is 21, 62, 72 and 37 percent for injecting manure, grass filters, soil testing and record keeping, respectively. This shows that adoption is in the early phase for record keeping, and in the maturity phase for grass filters and soil test.

Table 2: Descriptive Statistics

Variable	N	Mean	Std. Dev.	Range
Age	912	51.87	11.33	23-93
Iowa	919	0.51	0.5	0-1
Missouri	919	0.49	0.5	0-1
Education				
Less than High School	913	0.11	0.31	0-1
High School (Base Category)	913	0.43	0.5	0-1
Some College or Vocational School	913	0.28	0.45	0-1
Bachelor Degree	913	0.16	0.37	0-1
Graduate Degree	913	0.02	0.13	0-1
Off-farm Income				
None	872	0.3	0.46	0-1
$0 - $9,999	872	0.13	0.34	0-1
$10,000-$24,999 (Base Category)	872	0.16	0.37	0-1
$25,000 - $49,999	872	0.26	0.44	0-1
$50,000 - $99,999	872	0.12	0.33	0-1
$100,000 +	872	0.03	0.16	0-1
Farm Sales				
$10,000 - $99,999	892	0.28	0.45	0-1
$100,000-$249,999 (Base Category)	892	0.35	0.48	0-1
$250,000 - $499,999	892	0.19	0.39	0-1
$500,000 +	892	0.15	0.36	0-1
Environmental Perceptions				
Smell of Manure Bothers Me or Fam.	903	2.6	1.1	0-5
Smell of Manure Bothers My Neighbors	895	2.8	1.1	0-5
Not Sure How Crops Respond to Manure	892	2.1	1.2	0-5
Concerned about the Water Quality	901	4.2	1.1	0-5
Managing Manure Improves Water Quality	903	4.2	1.0	0-5
Regulations about Water Quality will be Stricter	909	4.0	1.0	0-5
Continue Farming				
Yes	868	0.9	0.3	0-1
No (Base Category)	868	0.03	0.17	0-1
Not Sure	868	0.1	0.3	0-1
Expand Livestock Numbers				
Yes	850	0.3	0.46	0-1
No (Base Category)	850	0.45	0.5	0-1
Not Sure	850	0.24	0.43	0-1

Table 2: Descriptive Statistics (Continued)

Variable	N	Mean	Std. Dev.	Range
Perceptions about the Practices				
Inject Manure				
Profitable	816	3.51	1.29	0-5
Improve Water Quality	807	3.87	1.11	0-5
Time Consuming	794	3.26	1.20	0-5
Complicated	792	2.81	1.18	0-5
Grass Filter				
Profitable	830	3.55	1.26	0-5
Improve Water Quality	836	4.33	0.96	0-5
Time Consuming	812	2.79	1.22	0-5
Complicated	807	2.48	1.15	0-5
Soil Test				
Profitable	839	4.17	1.11	0-5
Improve Water Quality	803	4.02	1.08	0-5
Time Consuming	800	2.97	1.26	0-5
Complicated	792	2.30	1.19	0-5
Record Keeping				
Profitable	836	3.34	1.31	0-5
Improve Water Quality	820	3.46	1.16	0-5
Time Consuming	823	3.57	1.20	0-5
Complicated	815	3.06	1.22	0-5
Roundup Ready Soybeans				
Profitable	842	3.85	1.19	1-5
Improve Water Quality	823	3.38	1.14	1-5
Time Consuming	813	1.88	1.08	1-5
Complicated	814	1.80	1.06	1-5
Manure Testing				
Profitable	836	3.44	1.25	1-5
Improve Water Quality	819	3.59	1.14	1-5
Time Consuming	809	3.05	1.15	1-5
Complicated	810	2.66	1.14	1-5
Calibrating Manure Spreaders				
Profitable	814	3.42	1.19	1-5
Improve Water Quality	798	3.51	1.12	1-5
Time Consuming	790	3.24	1.11	1-5
Complicated	787	3.03	1.12	1-5
Maintaining a Setback				
Profitable	840	3.37	1.33	1-5
Improve Water Quality	846	4.36	0.97	1-5
Time Consuming	818	2.47	1.24	1-5
Complicated	817	2.22	1.22	1-5

Table 2: Descriptive Statistics (Continued)

Variable	N	Mean	Std. Dev.	Range
Influence on Agricultural Decision				
Bank	884	2.3	1.2	0-5
Contractor	879	1.8	1.1	0-5
University	885	2.3	1.1	0-5
NRCS	886	2.6	1.2	0-5
Environmental Quality Incentives Program (EQIP)	921	0.18	0.39	0-1
Manure Handling				
Solid Handling	902	0.58	0.49	0-1
Liquid Handling (Base Category)	902	0.13	0.34	0-1
Solid and Liquid Handling	902	0.26	0.44	0-1
Total Animal Units	896	562.76	802.01	5-9800
Species Dummy				
Dairy	905	0.2	0.4	0-1
Beef Cow	905	0.2	0.4	0-1
Beef Cattle	905	0.14	0.35	0-1
Swine	905	0.27	0.44	0-1
Poultry	905	0.07	0.25	0-1
Turkey	905	0.11	0.31	0-1
Other	905	0.02	0.13	0-1
Contributes Significantly to Farm Work				
Farm Operator	904	0.97	0.18	0-1
Spouse	751	0.57	0.5	0-1
Other Family Member	921	0.41	0.49	0-1
Off-Farm Work				
Farm Operator Seasonal	891	0.14	0.37	0-1
Farm Operator Year Round	890	0.22	0.42	0-1
Spouse Seasonal	748	0.07	0.26	0-1
Spouse Year Round	747	0.5	0.5	0-1
Hours per Week Worked Off the Farm				
Farm Operator	859	11.69	18.72	0-100
Spouse	700	19.67	19.83	0-85
Other Family Member	919	7.68	18.75	0-100
Dependent Variables				
Injecting Manure	873	0.21	0.4	0-1
Grass Filter	828	0.61	0.5	0-1
Soil Test	811	0.72	0.4	0-1
Record Keeping	869	0.37	0.5	0-1
Roundup Ready Soybeans	874	0.53	0.50	0-1
Manure Testing	848	0.29	0.45	0-1
Calibrating Manure Spreaders	805	0.24	0.43	0-1
Maintaining a Setback	859	0.63	0.48	0-1

5.3. Environmental Perceptions

Farmers perceptions about the issues related to the environment are analyzed in this section. When farmers make decisions about adopting nutrient management practices, the overall perceptions of the farmer about environmental issues are expected to influence their decision. For example, if the farmer is concerned about water quality, then the farmer is expected to be more likely to adopt a nutrient management practice than a farmer who is not concerned about water quality.

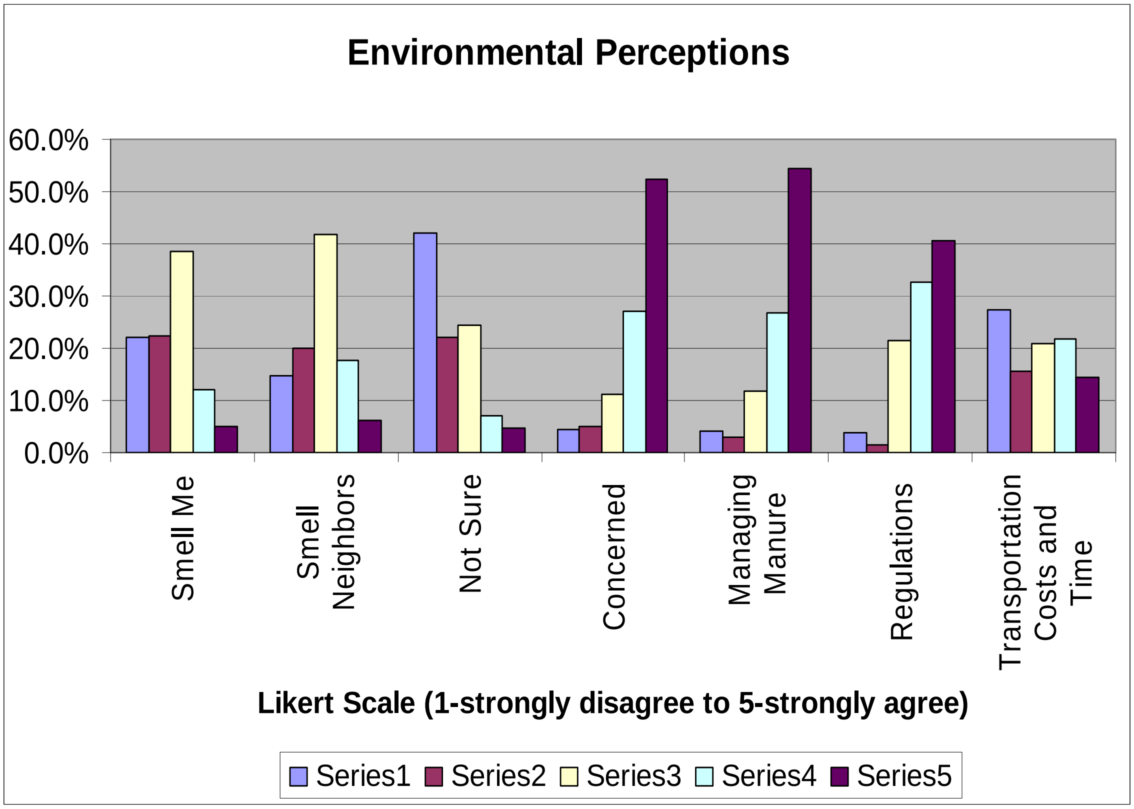
The statements that were asked in the survey were; the smell of manure bothers me or my family, the smell of manure bothers my neighbors, I am not sure how my crops would respond to manure as compared to commercial fertilizer, I am concerned about the water quality of streams and lakes in my county, properly managing manure improves water quality, agricultural regulations regarding water quality will become stricter in the next five years, and transportation costs and time affect which of my fields receive manure.

Figure 5 shows the environmental perceptions of farmers. In the figure, a choice of one indicates that the farmer strongly disagrees with the statement, three indicates that farmer neither agrees nor disagrees with the statement, and five indicates that the farmer strongly agrees with the statement. The vertical axis shows what percent of the farmers chose each Likert scale option for each of the statements. For example, for "the smell of manure bothers me", the left-most column shows that almost 22 percent of the farmers strongly disagreed with the statement.

In Figure 5, the most common answer is neither agree nor disagree for the statements smell of manure bothers me or my family, and smell of manure bothers my neighbors. Overall, not many farmers believe that the smell of manure bothers them or their neighbors. Concern about the smell of manure could impact the way manure is managed on the farm. For example, injecting manure into soil can be a response to the odor problem experienced by the neighbors.

Most farmers disagree with the statement that they are unsure about how their crops respond to manure. This is surprising as it is believed that farmers would not want to use manure as it might cause variability in nutrient supply to plants. Also, if farmers know how their plants would respond to manure, it is expected that they do soil testing and manure testing. A majority of the farmers are very concerned about water quality and believe that properly managing manure improves water quality. It is expected that these farmers are more likely to adopt nutrient management practices than farmers who disagree with these two statements. Finally, a majority of the farmers believe that regulations about water quality will be stricter in the next five years. Again, these farmers are expected to be more likely to adopt nutrient management practices than the farmers who disagree with the statement. Compared to the other questions, people seem to be divided as to whether time and costs affect which fields receive manure. We would expect people who agree would be more likely to view manure as a waste rather than a resource.

Figure 5: Environmental Perceptions



5.4. Descriptive Statistics by Farm Sales

As farm sales are one of the most important factors that determine the adoption of a new technology as shown in the literature review, in this section some of the descriptive statistics are analyzed with respect to farm sales categories. Figure 6 shows the relationship between education and gross farm sales. It is seen that the majority of farmers with less than a high school education are in the lowest farm sales category and there are very few farmers with this education level in the highest sales categories. Otherwise, there is no clear correlation between education level and farm sales. For the farm sales category of $100,000-$249,999 there is almost an even distribution of different educational levels. The highest farm sales category $500,000, has slightly lower percentage of farmers with high school education than farmers with higher than high school education.

Figure 6: Education versus Farm Sales

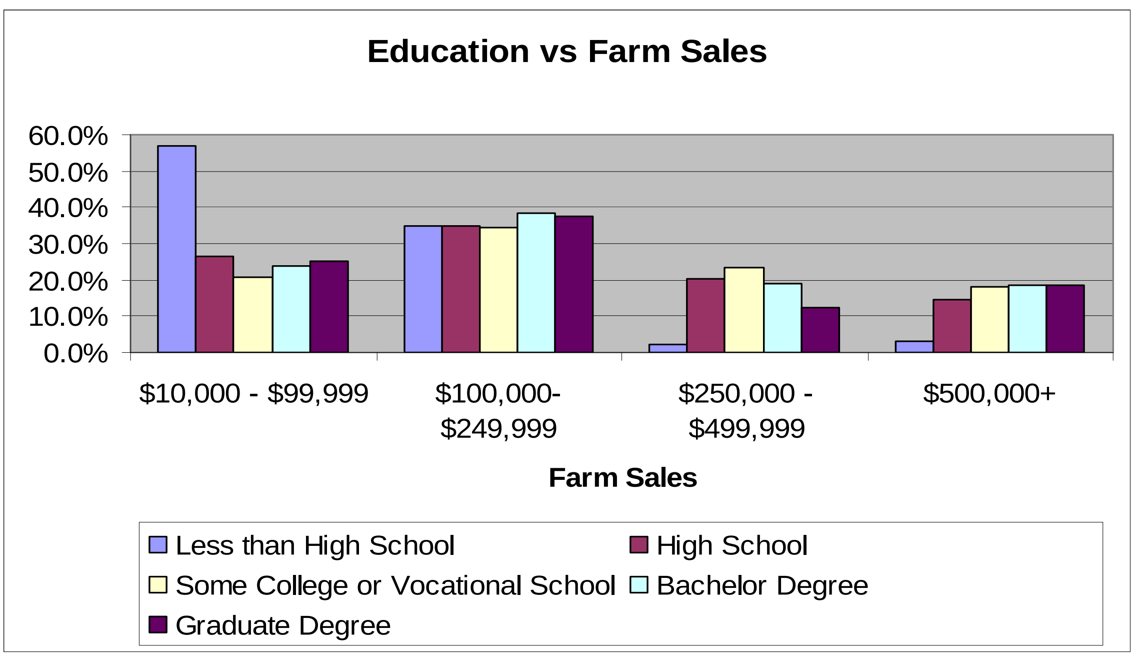


Table 3 combines environmental perceptions with gross farm sales. Overall, there is no significant change in the perceptions with farm sales. Being concerned about the water quality and managing manure improves water quality have higher mean for all farm sales categories than other perceptions.

Table 3: Environmental Perceptions by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000-$249,999	$250,000 - $499,999	$500,000 +
Environmental Perceptions	Mean	Mean	Mean	Mean
Smell of Manure Bothers Me or My Family	2.6	2.5	2.5	2.5
Smell of Manure Bothers My Neighbors	2.8	2.8	2.8	2.9
Not Sure How Crops Respond to Manure	2.3	2.1	2.1	1.8
Concerned about the Water Quality	4.1	4.2	4.2	4.3
Managing Manure Improves Water Quality	4.1	4.3	4.3	4.4
Regulations about Water Quality will be Stricter	3.9	4.1	4.1	4.2

Table 4 combines future expectations with gross farm sales. As the farm sales increase, there is a rough increase in the percentage of farmers that plan to continue farming in the next 5 years. Farm sales category $10,000-$99,999, the lowest category, has the highest percentage of farmers that do not plan to continue farming in the next 5 years.

Table 4: Future Expectations by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000- $249,999	$250,000 - $499,999	$500,000 +
	Mean (%)	Mean (%)	Mean (%)	Mean (%)
Continue Farming in Next 5 Years Yes	79.7%	87.7%	94.9%	91.9%
Continue Farming in Next 5 Years No	4.3%	3.0%	0.6%	2.4%
Continue Farming in Next 5 Years Not Sure	15.6%	8.3%	4.4%	4.9%
Column Sum	100.0%	100.0%	100.0%	100.0%

Table 5 also combines future expectations with gross farm sales. As the farm sales increase the percentage of farmers who plan to expand their livestock numbers in the next 5 years increases. Around 52 percent of farmers with the lowest farms sales do not plan to increase the livestock numbers versus 36 percent for the highest farm sales category.

Table 5: Future Expectations by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000- $249,999	$250,000 - $499,999	$500,000 +
	Mean (%)	Mean (%)	Mean (%)	Mean (%)
Expand Livestock Numbers Yes	27.1%	28.2%	35.7%	37.8%
Expand Livestock Numbers No	51.6%	48.0%	38.9%	36.1%
Expand Livestock Numbers Not Sure	20.9%	22.4%	24.8%	26.1%
Column Sum	100.0%	100.0%	100.0%	100.0%

Table 6 combines contribution to farm work with gross farm sales. For all farm sales categories the percentage of farms with farm operator contributing significantly to farm work is over 94 percent. The percentage of farms for which the spouse contributes significantly to farm work is between 58 to 60 for all farm sales categories except the largest one, which is about 51 percent. The contribution of "other family member" increases as farm sales increase, and in particular, there is a jump from the medium sized farm ($100,000 to 249,000) to the farms with sales over $250,000. This may indicate that the operation provides income for more than one nuclear family.

Table 6: Contribution to Farm Work by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000- $249,999	$250,000 - $499,999	$500,000 +
Contributes Significantly to Farm Work	**Mean (%)**	**Mean (%)**	**Mean (%)**	**Mean (%)**
Farm Operator	94.6%	96.8%	98.8%	99.3%
Spouse	58.5%	58.4%	60.4%	50.8%
Other Family Member	36.0%	38.4%	51.8%	53.7%

5.5. Off-Farm Income and Off-Farm Work

Table 7 combines off-farm income and farm sales. As farm sales increase, the percentage of farmers who do not have off-farm income increases. A quarter of farmers in the lowest sales category have no off-farm income which indicates that they have low total incomes. It is also seen that the off-farm income category $25,000-$49,000 is the most common category, for those with some off-farm income.

Table 7: Off-Farm Income by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000- $249,999	$250,000 - $499,999	$500,000 +
Off-Farm Income	Mean (%)	Mean (%)	Mean (%)	Mean (%)
No off-farm Income	24.8%	28.6%	32.1%	41.1%
$0 - $9,999	14.5%	12.7%	13.9%	10.1%
$10,000-$24,999	17.1%	17.2%	12.7%	16.3%
$25,000 - $49,999	26.5%	29.5%	21.8%	21.7%
$50,000 - $99,999	13.7%	9.7%	15.8%	9.3%
$100,000 +	3.4%	2.3%	3.6%	1.6%
Column Sum	100.0%	100.0%	100.0%	100.0%

Table 8 combines off-farm income with type of livestock operation. Dairy cattle operations have the largest percentage for no off-farm income. This is well-known as a labor-intensive operation and there were no respondents with over $100,000 off-farm income. Again, the off-farm income category $25,000-$49,000 is the most common category for all types of operations, except for turkey operations, where the $10,000-$24,999 is the most common category.

Table 8: Off-Farm Income by Primary Livestock Type of the Operation

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
No off-Farm Income	50.6%	27.2%	21.3%	21.2%	28.3%	33.7%
$0 - $9,999	14.1%	12.4%	9.0%	14.2%	10.0%	17.9%
$10,000-$24,999	14.1%	17.8%	13.9%	16.4%	16.7%	19.0%
$25,000 - $49,999	15.3%	30.2%	35.3%	28.8%	30.0%	16.8%
$50,000 - $99,999	5.9%	9.5%	16.4%	15.5%	11.7%	10.5%
$100,000 +	0.0%	3.0%	4.1%	4.0%	3.3%	2.1%
Column Sum	100%	100%	100%	100%	100%	100%

Table 9 combines the off-farm income and future expectations of farmers. There is not a clear relation between off-farm income and continue farming in the next 5 years. However, for both farmers who plan and do not plan to continue farming, the off-farm income category $25,000-$49,999 is the most common group for those with off-farm income. This is also same for the statement "expand livestock numbers in the next 5 years." The group most likely to say they will expand is the one with $25,000-$49,999 off-farm income, more than those with no off-farm income. This would indicate that the capital to expand may be a limiting constraint.

Table 9: Off-Farm Income versus Future Expectations

	Continue Farming in Next 5 Years			Expand Livestock Numbers in Next 5 Years		
	Yes	**No**	**Not Sure**	**Yes**	**No**	**Not Sure**
No off-Farm Income	28.5%	23.1%	34.6%	22.2%	32.7%	29.5%
$0 - $9,999	13.3%	23.1%	12.8%	13.3%	13.6%	15.3%
$10,000-$24,999	15.6%	11.5%	21.8%	17.3%	15.2%	15.8%
$25,000 - $49,999	27.1%	30.8%	21.8%	29.8%	23.8%	29.0%
$50,000 - $99,999	12.6%	7.7%	6.4%	14.5%	11.6%	8.4%
$100,000 +	3.0%	3.9%	2.6%	2.8%	3.1%	2.1%
Column Sum	100%	100%	100%	100%	100%	100%

Table 10 shows the relation between off-farm work of the farm operator and gross farm sales. The percentage of farmers who have year round off-farm work decreases as farm sales increase and the percentage of operators with no off-farm work increases with size. However for seasonal off-farm work, farmers with farm sales $100,000-$249,999 are slightly more likely than farmers with farm sales of $10,000-$99,999 to have seasonal work. Note that for all but the lowest farm sales category, the majority of operators have no off-farm work.

Table 10: Off-Farm Work of Farm Operator by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000- $249,999	$250,000 - $499,999	$500,000 +
Off-Farm Work	**Mean (%)**	**Mean (%)**	**Mean (%)**	**Mean (%)**
Farm Operator None	47.9%	62.3%	76.8%	86.6%
Farm Operator Seasonal	16.7%	17.5%	12.2%	7.5%
Farm Operator Year Round	35.5%	20.1%	11.0%	6.0%
Column Sum	100%	100%	100%	100%

Table 11 combines off-farm work of the spouse with gross farm sales. The relation between off-farm work of the spouse and farm sales is less clear than that of farm operator and farm sales. For seasonal work, the farms with the 2 largest farm sales categories have lower percentages than the farms with other 2 farm sales categories. There is no clear trend between year round off-farm work of the spouse and the farm sales, although the highest sales category has a higher percentage of spouses who do not work. Some spouses may have careers and others just jobs which may explain the lack of a trend.

Table 11: Off-Farm Work of Spouse of the Farm Operator by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000- $249,999	$250,000 - $499,999	$500,000 +
Off-Farm Work	**Mean (%)**	**Mean (%)**	**Mean (%)**	**Mean (%)**
Spouse None	43.4%	39.9%	42.7%	49.1%
Spouse Seasonal	8.5%	8.5%	4.0%	5.2%
Spouse Year Round	48.1%	51.6%	53.3%	45.7%
Column Sum	100%	100%	100%	100%

Table 12 combines non-family labor with gross farm sales. It is seen that as the farm's sales increase, the percentage of farms hiring non-family labor increases. This shows the labor requirements for production increase as farm size increases. Almost a third of farmers in the lowest sales category hire non-family labor. This may explain the fairly low number of respondents who indicate off-farm work interferes with farming.

Table 12: Non-Family Labor by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000-$249,999	$250,000 - $499,999	$500,000 +
	Mean (%)	Mean (%)	Mean (%)	Mean (%)
Hire Non-Family Labor Yes	32.1%	45.5%	60.0%	74.2%
Hire Non-Family Labor No	67.9%	54.5%	40.0%	25.8%
Column Sum	100%	100%	100%	100%

Table 13 shows hours worked off the farm and gross farm sales. For the farm operator, as farm sales increase, the average hours per week worked off the farm decreases. This is in line with the percentage of farm operators working off the farm. The relation is less clear for the spouse. However, at each farm sales category, the spouse has higher hours worked off the farm than the farm operator.

Table 13: Hours Worked Off the Farm by Gross Farm Sales (Combined Crop and Livestock Sales)

	Farm Sales			
	$10,000 - $99,999	$100,000-$249,999	$250,000 - $499,999	$500,000 +
Hours worked Off the Farm	Mean (Hours / Week)	Mean (Hours / Week)	Mean (Hours / Week)	Mean (Hours / Week)
Farm Operator	17	12	7	4
Spouse	19	21	18	19
Other Family Member	8	8	10	4

Table 14 shows whether off-farm interferes with the timing of farming operation for different off-farm income categories. Note that off-farm income is now in columns. In general off-farm income does not need to come from a current job. Sources like retirement income and interest income can also be the source of off-farm income. However, if the off-farm income is created by currently working off the farm, it is expected that farmers with higher off-farm income, hence more time spent off the farm, would have more conflicts between the farm operations and off-farm work. As far as adoption of practices, a labor intensive practice such as record keeping would not be adopted by a farmer who has conflicts between farming operations and off-farm work.

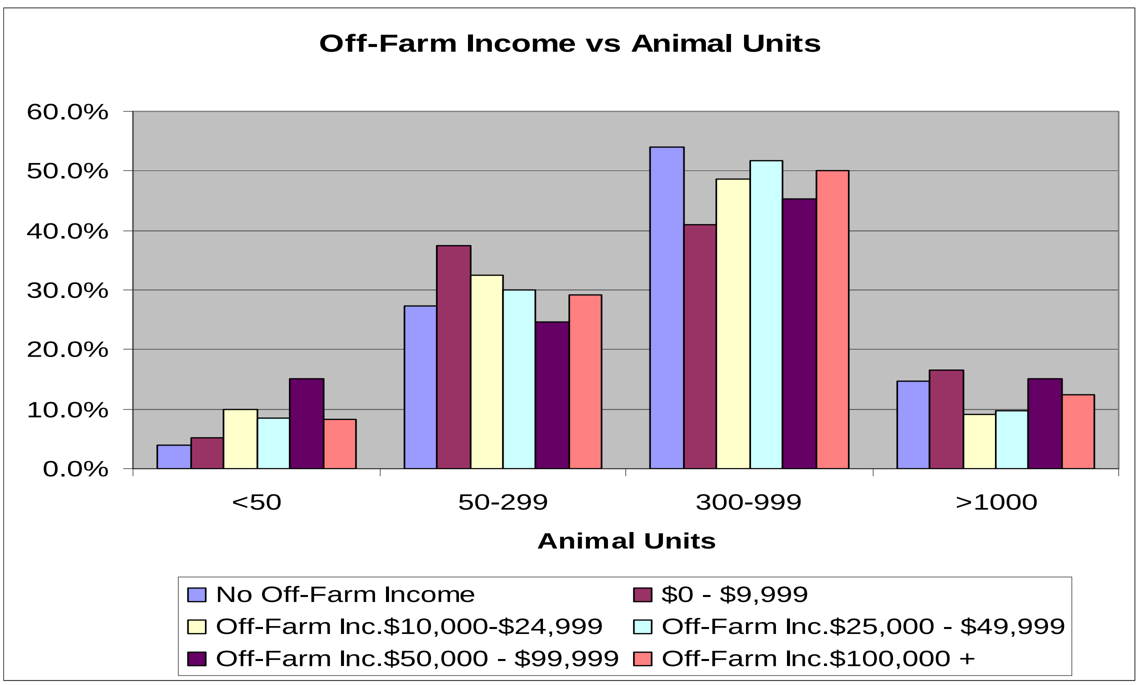
From Table 14 it is seen that as off-farm income increases, the percentage of farmers who answered “yes” to the question increases except for the off-farm income category of $100,000 and above. It is seen that a majority of the farmers with off-farm income of $100,000 and above said “no” as to whether off-farm work interferes with farming operations. This is probably due to the fact that farmers in the highest off-farm income category have small farms. This is also evident from Table 10; farm operators of the lowest farm sales category have higher percentage of farmers working off the farm.

Table 14: Off-Farm Work Interferes with the Timing of Farming Operation by Off-Farm Income Categories

Off-Farm Work Interfere	No off-farm Income	$0 - $9,999	$10,000-$24,999	$25,000 - $49,999	$50,000 - $99,999	$100,000 +
No	43.8%	60.2%	60.8%	50.0%	37.1%	60.0%
Yes	0.0%	15.9%	19.6%	27.7%	48.6%	40.0%
Not Applicable	56.2%	23.9%	19.6%	22.3%	14.3%	0.0%
Column Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 7 depicts the relation between off-farm income and number of animal units in a livestock operation. It is seen that as the animal units increase from less than 50 to 300-999, the percentage of the farmers with off-farm income in each category increases which is somewhat surprising given that livestock production is relatively labor intensive. However, for the farms with more than 1000 animal units, the percentage of farms decreases for all off-farm income categories. It is also seen that animal unit category 300-999 has the largest share of farmers for all off-farm income categories.

Figure 7: Off-Farm Income Category versus Animal Units in the Livestock Operation



5.6. Environmental Perceptions and Off-Farm Income

In this section the interaction between farmers' perceptions about environmental issues and having off-farm income is analyzed. It is important to know whether farmers with more off-farm income are more concerned about the environment since this can help to analyze the impact of off-farm income on adoption of nutrient management practices.

Figure 8 shows the relation between the statement "I am not sure how my crops would respond to manure as compared to commercial fertilizer" and off-farm income. For example, the left most bar indicates that around 52 percent of the farmers with no off-farm income strongly disagree with the statement "I am not sure how my crops would respond to manure as compared to commercial fertilizer." Few farmers agree with this statement and this is similar for all off-farm income categories. Hence, this might show that the response to this question does not differ by off-farm income level. It is notable that the highest percentage of farmers who strongly disagree with the statement are those with the highest incomes.

Figure 8: I'm not Sure How My Crops Would Respond to Manure as Compared to Commercial Fertilizer versus Off-Farm Income

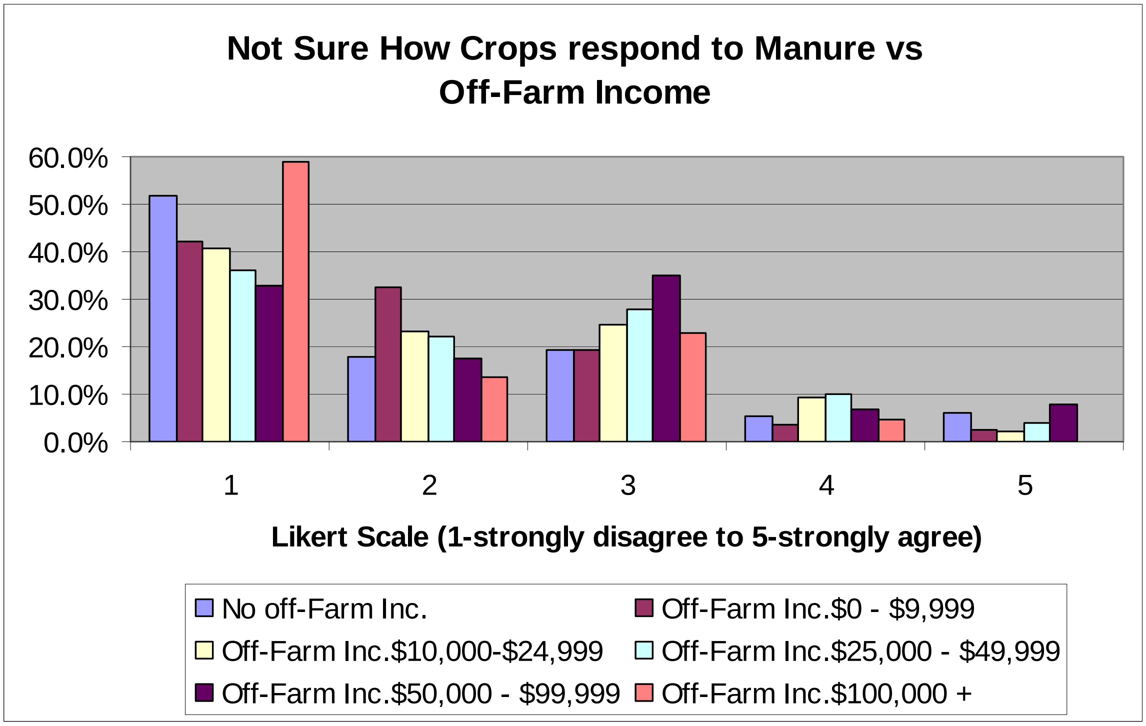


Figure 9 shows the relation between being concerned about the water quality of the streams and lakes in their county and off-farm income. For all off-farm income categories, the most common response is that they strongly agree that they are concerned with the water quality of the streams and lakes in their county. Those with the highest incomes are the most likely to strongly agree. This coincides with environmental economics literature that preferences for the environment are higher among those with higher incomes.

Figure 9: I am Concerned about the Water Quality of the Streams and Lakes in My County versus Off-Farm Income

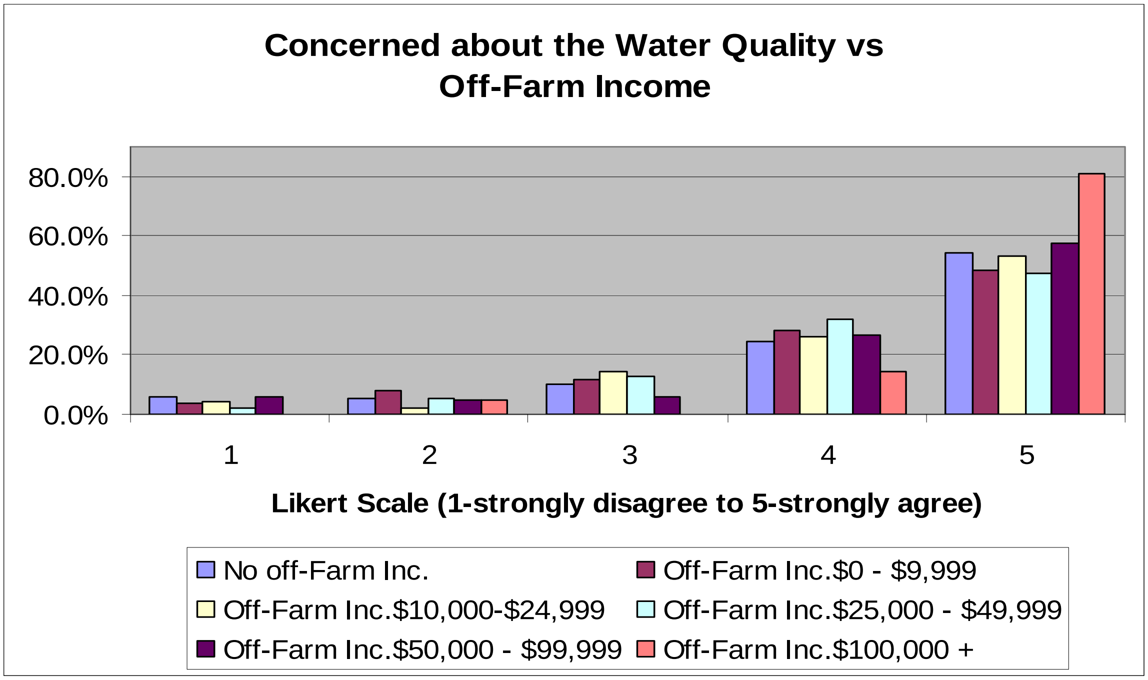


Figure 10 shows the relationship between the statement "properly managing manure improves water quality" and off-farm income. For all off-farm income categories, the highest percentages of farmers strongly agree that properly managing manure improves water quality. Those with incomes over $100,000 are the most likely to strongly agree and none of those farmers disagree with the statement.

Figure 10: Properly Managing Manure Improves Water Quality versus Off-Farm Income

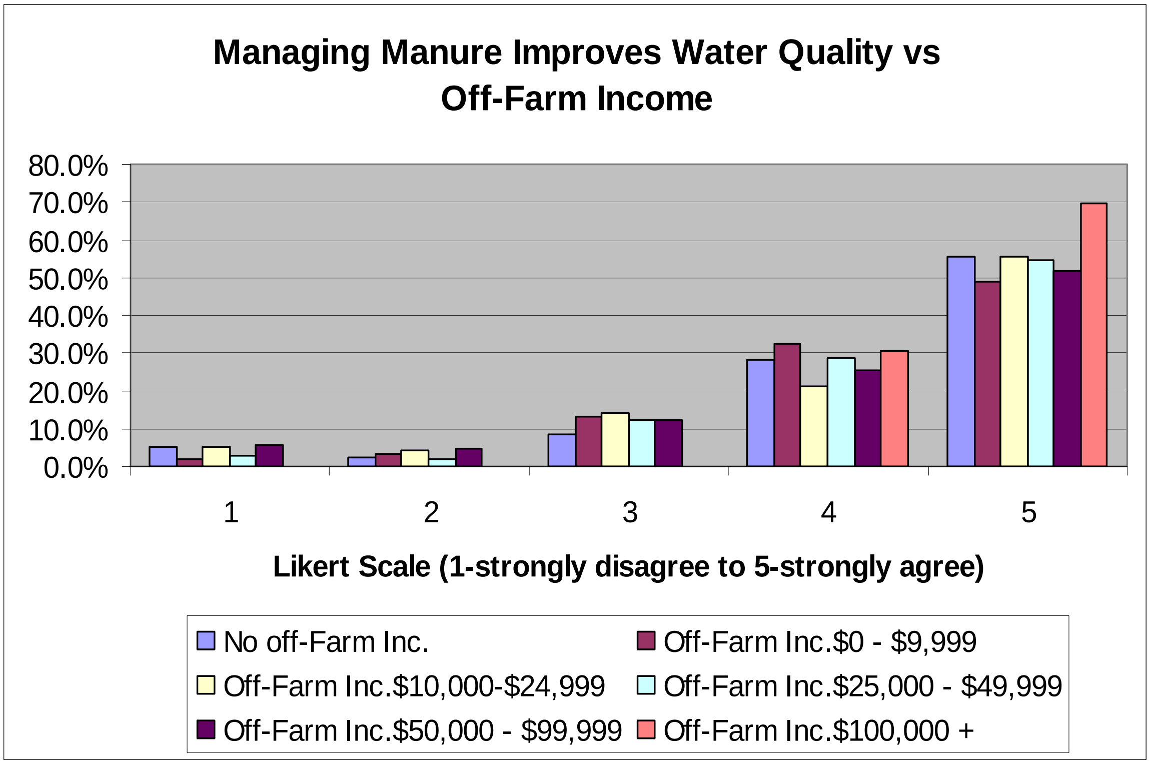
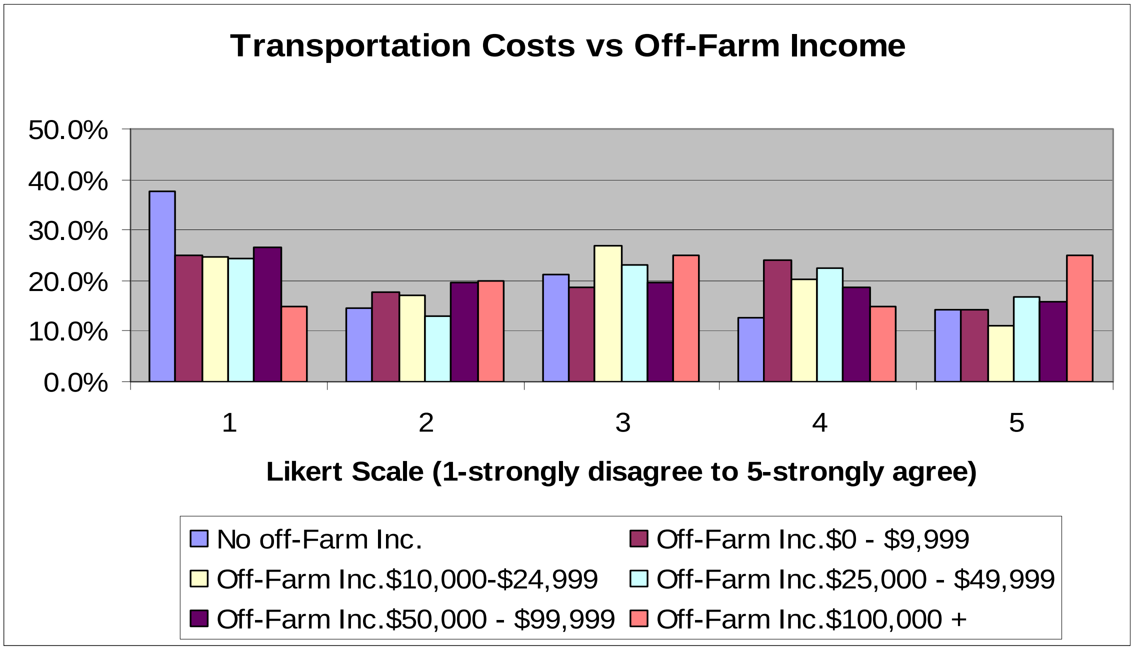


Figure 11 shows the relation between the statement "transportation costs and time affect which of my fields receive manure" and off-farm income. It is seen that there is an almost even distribution of farmers across the different response categories to the statement and different off-farm income categories. Farmers with no off-farm income are most likely to strongly disagree with the statement that transportation costs and time affect which of their fields receive manure. As farmers with no off-farm income probably have more time available for farming, the results shows that time is more of an issue than transportation costs. This is also supported by the fact farmers with highest off-farm income category most like to strongly agree with the statement.

Figure 11: Transportation Costs and Time Affect Which of My Fields Receive Manure versus Off-Farm Income



5.7. Manure Handling Systems and Cropped Land

Manure handling systems refer to the way manure is collected from animal houses, stored and land applied. In the survey, farmers were asked how they manage manure and there were 8 manure management structure and / or equipment choices. These 8 choices were then classified into solid and liquid manure handling systems. There were farmers who only used either solid or liquid manure handling systems, and some farmers used both solid and liquid manure handling systems. Since the way manure is handled on the farm impacts which nutrient management practices are relevant and may be adopted, it is important to see the proportion of farmers with solid, liquid or both manure handling systems for each livestock types. The way manure is handled depends on the type of the livestock in the farming operation. It should be noted that there can be two different livestock species on a farm, which may require different manure handling systems.

Table 15 shows the type of manure handling system for the type of livestock operation. For example, 53 percent of the dairy cattle farms use a solid manure handling system, while 46 percent use both solid and liquid manure handling system. In this case it would be expected that the 53 percent of the dairy cattle farmers are not able to use manure injecting equipment, which requires liquid or slurry manure. The majority of beef cattle and beef cow operations have solid manure handling systems. Swine operations mostly have liquid and both solid and liquid manure handling systems. It may be the case that some swine operations have another species of livestock, for which they use a solid manure handling system and thus have both systems. It may also be that they have an older facility as well as a newer one. A majority of the broiler and turkey operations have only solid manure handling systems. Overall, it is expected that injecting manure would be adopted by mostly swine and dairy cattle operations.

Table 15: Type of Manure Handling System by Livestock Species

Manure Handling System	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
Solid Only	52.9%	79.2%	74.8%	12.5%	90.3%	93.9%
Liquid Only	1.2%	0.0%	3.4%	45.4%	3.2%	0.0%
Both Solid and Liquid	46.0%	18.0%	7.6%	42.1%	4.8%	6.1%

Table 16 shows the percentage of farmers with different manure handling systems for animal unit categories. It is seen that as animal units increase, the percentage of farmers with solid handling systems decreases. However, the number of farmers with both solid and liquid manure handling systems increases as the number of animal increase. This may be due to farmers with more animal units having different livestock species that require different manure handling systems or to having a combination of old and new facilities. The number of the farmers with liquid manure handling systems increases with animal units except for the category 50 to 299 animal units.

Table 16: Type of Manure Handling System by Animal Units

Manure Handling System	<50	50-299	300-999	>1000
Solid Only	70.7%	69.3%	52.6%	36.1%
Liquid Only	9.8%	0.0%	16.4%	29.3%
Both Solid and Liquid	4.9%	22.0%	31.0%	33.3%

As the farm sales include sales from both livestock and crop production, it is important to see the actual acres of land cropped by farm sales and livestock species. Acres of land cropped is also important in terms of the amount of manure produced per acre. If the amount of manure per acre is high, then farmers might have to spread more manure than the crops need, hence causing leaching and run-off problems from the excess nutrients.

Table 17 shows the mean of cropped acres by farm sales and livestock species. It is seen that mean cropped acres increases monotonically with farm sales for all livestock species except for turkey operations. Beef cow operations seem to have the highest mean cropped acres for all farm sales categories. For the highest farm sales category, it is interesting to see an increase for broiler operations and the decrease for turkey operations. This suggests that the share of crop production increases for broiler operations and decreases for turkey operations. In Missouri and Iowa, most livestock farms have an important crop production component, which is different from some other areas such as North Carolina, so it would be more likely that manure would be viewed as an on-farm resource rather than a waste product.

Table 17: Mean Cropped Acres by Livestock Species

Farm Sales	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	206	287	416	190	133	207
$100,000-$249,999	371	607	707	422	504	311
$250,000 - $499,999	486	1017	1758	947	645	796
$500,000 +	971	1493	1900	1211	1513	191

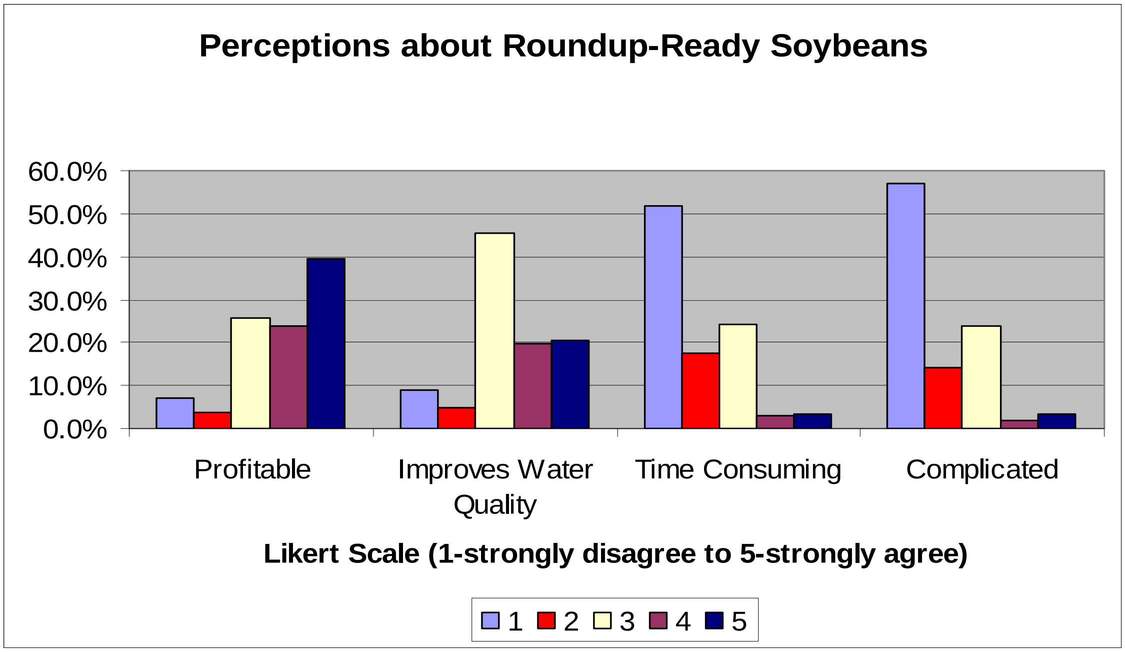
5.8. Perceptions and Adoption Rate of Practices

Perceptions and adoption rates for the practices included in the survey will be analyzed in this section. Since the survey sampling is done by stratification based on farm sales and type of the operation, data on adoption rates are presented by farm sales and species. Since the adoption rate differs by the size of the farm and the type of the operation, representation of the data this way enables one to make inferences. Also, when presenting the data, beef producers (the category the data were stratified by) are separated into beef cattle and beef cow producers based on their responses to the survey.

5.8.1. Roundup Ready soybeans

Figure 12 shows the perceptions of farmers about Roundup Ready soybeans. Most of the farmers believe that it is a profitable, non time consuming and uncomplicated practice. Almost 40 percent of the farmers believe it improves water quality, but a large percentage is neutral or unsure.

Figure 12: Perceptions about Using Roundup Ready Soybeans



The adoption rate for Roundup Ready soybeans, for operations that grow soybeans, is given in Table 18. For example, 53.85 percent of the dairy cattle farmers with farm sales between $10,000 and $99,999, who returned the survey and grow soybeans, adopted Roundup Ready soybeans. For beef cattle and beef cow operations, adoption rate increases with farm sales and this is generally true for other categories except for farm sales with $500,000 and above. Overall, the adoption rate is high for all categories, especially for the farms with farm sales above $100,000. Increasing adoption rate with farm sales can imply that larger farms can afford to pay a higher price for Roundup Ready than the regular soybeans or that the benefits are obtained over a larger number of acres.

Table 18: Adoption Rate of Roundup Ready Soybeans by Primary Livestock Type of the Operation and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	53.85%	75.00%	76.19%	85.71%	-	40.00%
$100,000-$249,999	84.00%	86.05%	81.48%	90.74%	70.00%	50.00%
$250,000 - $499,999	100.00%	96.55%	100.00%	97.37%	87.50%	75.00%
$500,000 +	95.45%	100.00%	100.00%	96.77%	50.00%	66.67%

5.8.2. Soil testing

Figure 13 shows the perceptions of farmers about testing soil for nutrients at least every three years. The majority of the farmers believe testing soil for nutrients is a profitable and uncomplicated practice. Also, most of the farmers believe that testing soil improves water quality. However, there is not a clear picture regarding being time consuming.

Figure 13: Perceptions about Testing Soil for Nutrients at Least Every Three Years

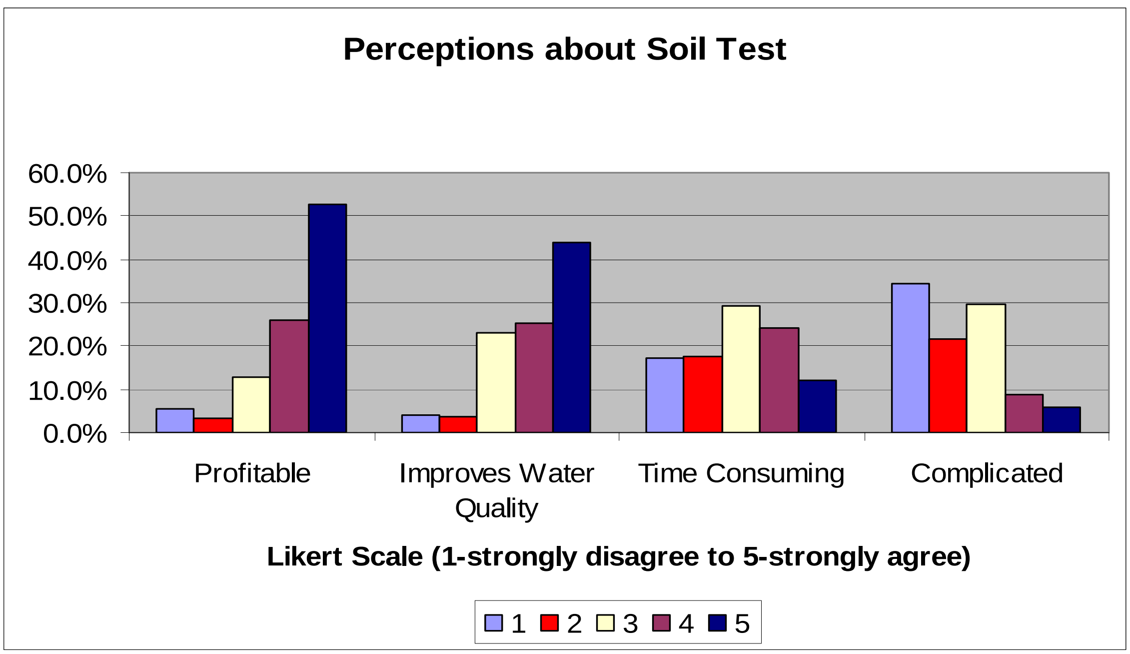


Table 19 shows the adoption rates for soil testing. For most species, the lowest two farm sales categories have lower adoption rates than the top two farm sales categories. Larger farms might have higher manure available per acre, hence are more inclined to test the soil for nutrients before purchasing commercial fertilizer.

Table 19: Adoption Rate of Soil Test by Primary Livestock Type of the Operation and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	56.67%	70.97%	64.86%	75.00%	57.14%	47.06%
$100,000-$249,999	55.32%	80.85%	62.86%	82.86%	82.35%	75.86%
$250,000 - $499,999	78.38%	96.88%	100.00%	77.27%	86.67%	75.00%
$500,000 +	95.65%	86.11%	100.00%	83.33%	100.00%	57.14%

5.8.3. Manure testing

Figure 14 shows the perceptions of farmers about testing manure for nutrients at least annually. Farmers tend to believe that it is a profitable practice and also that it improves water quality. For all perceptions, there is a significant number of farmers who neither agree nor disagree with the statements. Almost 20 percent of the farmers believe testing manure is complicated and 40 percent believe the opposite.

Figure 14: Perceptions about Testing Manure for Nutrients at Least Annually

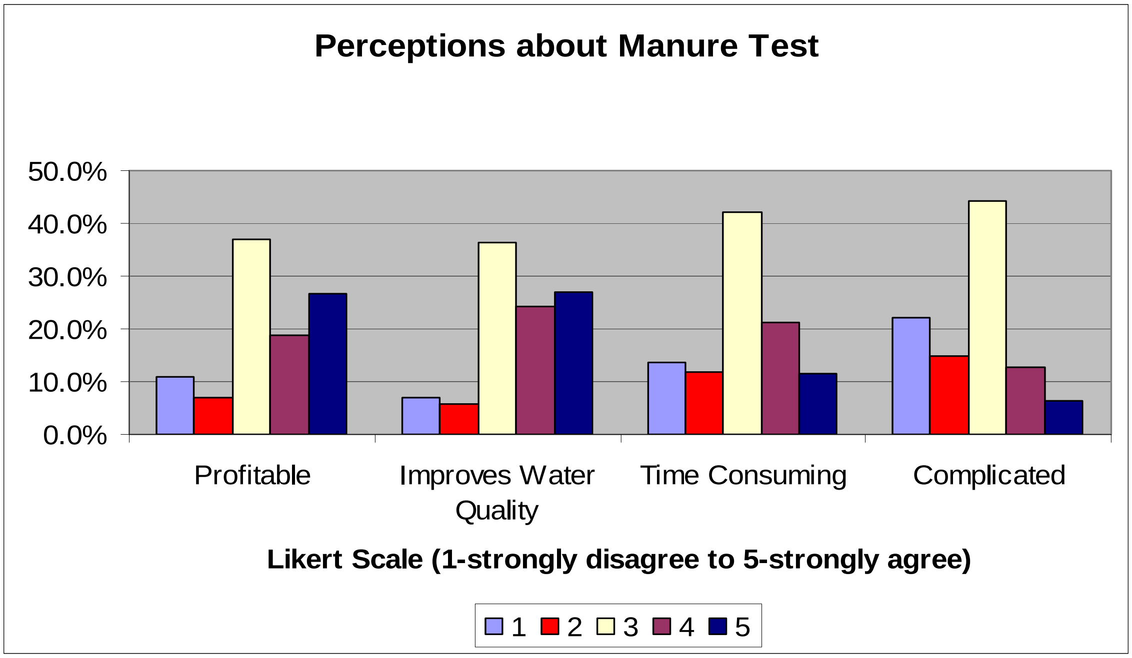


Table 20 shows the adoption rates for testing manure for non-pasture operations. Since pasture-only operations do not collect the manure to be disposed of later, they are excluded from the analysis. Adoption rate increases monotonically with farm sales for dairy cattle, swine and turkey operations. Beef cow operations have the lowest adoption rates among all species and beef cattle adoption rates are relatively low.

Table 20: Adoption Rate of Manure Testing by Primary Livestock Type of the Operation and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	8.11%	12.50%	4.26%	36.36%	0.00%	16.13%
$100,000-$249,999	16.07%	4.08%	5.00%	52.50%	48.00%	37.21%
$250,000 - $499,999	34.15%	15.63%	7.14%	54.76%	46.67%	55.56%
$500,000 +	70.37%	24.32%	0.00%	63.41%	33.33%	71.43%

5.8.4. Maintaining setbacks

Figure 15 shows the perceptions of farmers about maintaining a setback of 100 feet between streams and lakes and manure application areas. In general farmers believe this practice improves water quality, is not time consuming and is not complicated. Compared to manure testing, it is very obvious to farmers that this practice improves water quality. Also, around 45 percent of the farmers believe this practice is profitable.

Figure 15: Perceptions about Maintaining a Setback between Streams and Lakes and Manure Application Areas of 100 Feet

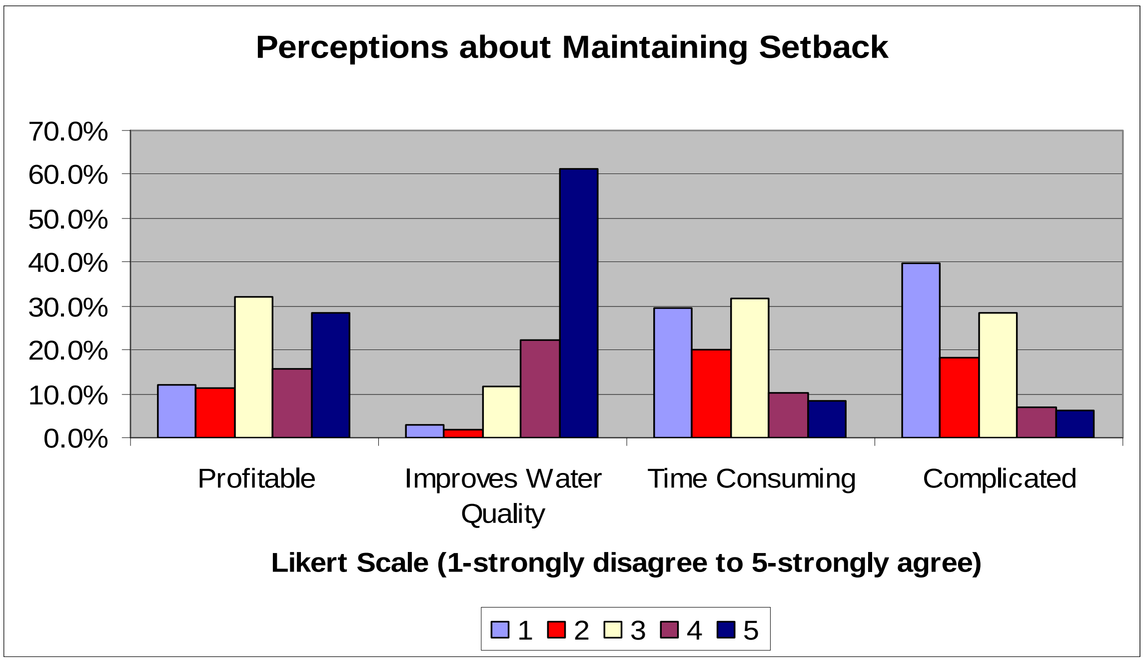


Table 21 shows adoption rates for maintaining a setback of 100 feet between streams and lakes and manure application areas. Adoption rate increases monotonically with farm sales for dairy cattle, beef cattle, beef cow and swine operations. This may imply that larger farms are more capable of setting aside some part of their land as setbacks. However, overall the adoption rate is fairly high for all groups. Although broiler and turkey farms have similar manure management systems, the adoption rate for the farms sales group between $10,000 and $99,999 differs significantly between two, which is surprising. For both groups, adoption rates drop for the highest sales category.

Table 21: Adoption Rate of Maintaining a Setback by Primary Livestock Type of the Operation and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	36.36%	58.62%	52.63%	42.11%	28.57%	83.33%
$100,000-$249,999	52.17%	62.75%	69.44%	65.75%	77.78%	63.64%
$250,000 - $499,999	64.10%	67.65%	70.00%	81.82%	81.25%	75.00%
$500,000 +	84.00%	73.68%	80.00%	82.05%	50.00%	42.86%

5.8.5. Injecting manure

Figure 16 shows the perceptions of farmers about injecting manure into the soil during application. Overall, farmers believe the practice is profitable and improves water quality, but it is also time consuming. Farmers are split as to whether it is complicated with a large proportion choosing the middle category.

Figure 16: Perceptions about Injecting Manure into the Soil during Application

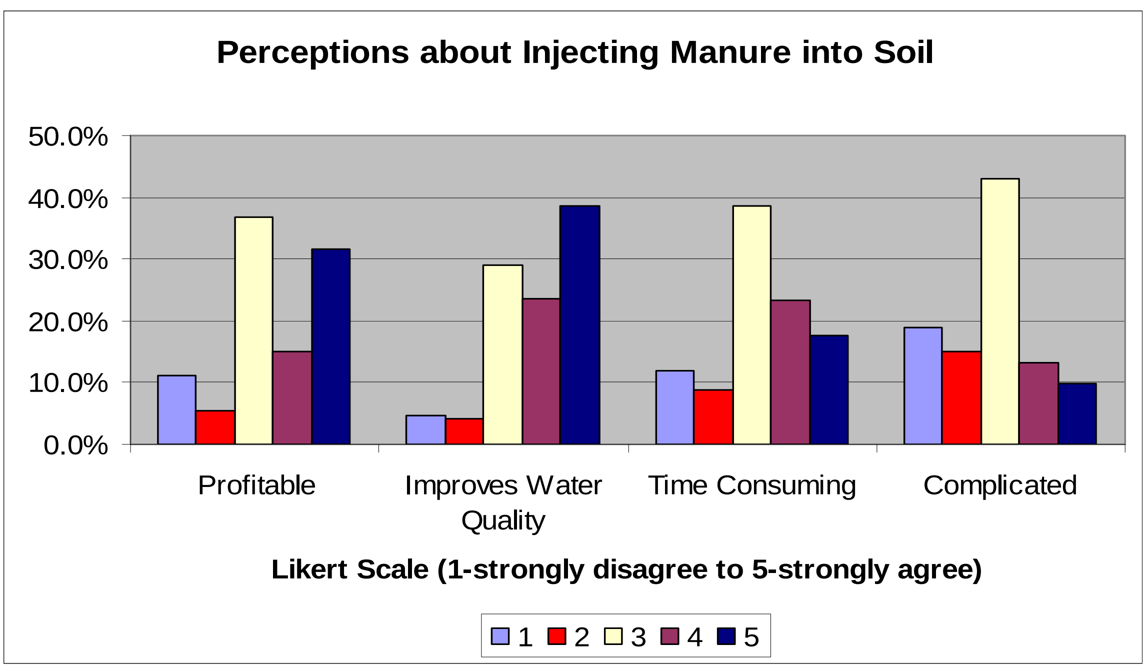


Table 22 shows the adoption rates for injecting manure. Injecting requires liquid or slurry manure so this is not feasible for all farming systems. Adoption rate increases with farm sales for dairy cattle and swine operations. This is mostly because these operations are more likely to have liquid waste management systems such as lagoons. The "-" refers to cases where the answer is left blank for the question by all respondents represented by that cell.

Table 22: Adoption Rate of Injecting Manure by Primary Livestock Type of the Operation and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	12.50%	33.33%	0.00%	45.16%	-	0.0%
$100,000-$249,999	15.79%	0.00%	0.00%	50.72%	-	-
$250,000 - $499,999	34.78%	57.14%	0.00%	59.52%	33.3%	100.0%
$500,000 +	57.14%	41.67%	100.00%	89.19%	-	50.0%

5.8.6. Calibrating manure spreaders

Figure 17 shows the perceptions of farmers about calibrating manure spreaders at least annually. Overall, farmers believe that calibrating manure spreaders is a profitable practice, which also improves water quality. However, around 35 percent of the farmers believe this practice is time consuming. A large number of farmers chose the middle category for all characteristics.

Figure 17: Perceptions about Calibrating Manure Spreaders at Least Annually

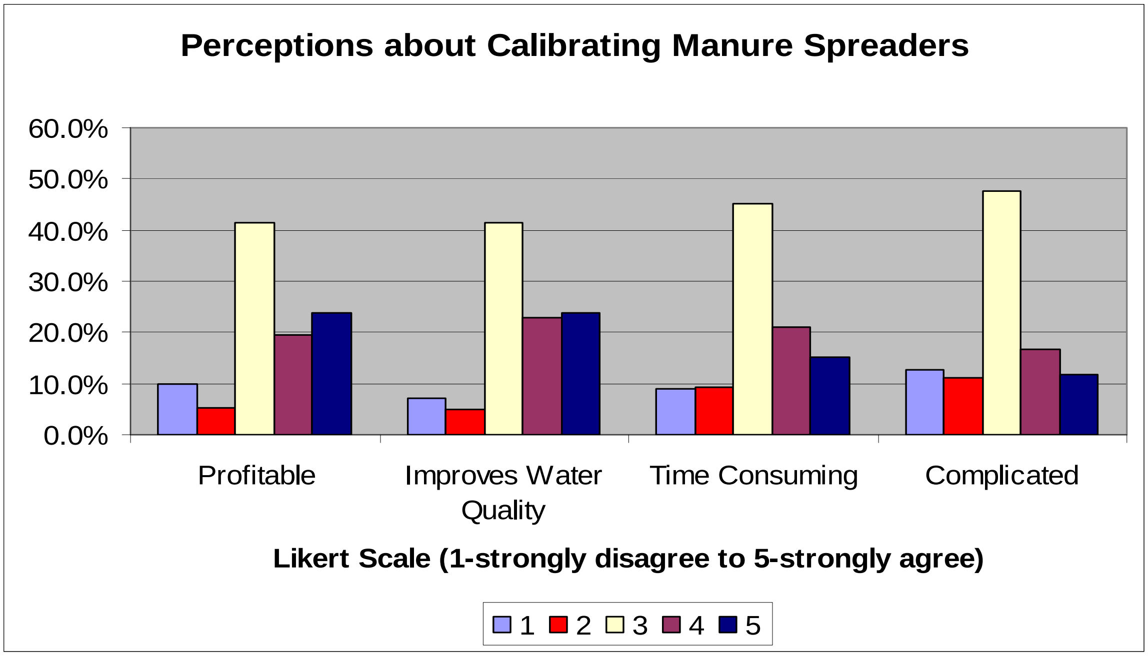


Table 23 shows the adoption rates for calibrating manure spreaders. It is important to calibrate manure spreaders to spread the manure to meet plant nutrient requirements while minimizing runoff. Adoption rates increase monotonically with farm sales for all species except for beef cattle, beef cow and turkey operations. In general, the lowest two farm sales categories have lower adoption rates than the top two farm sales categories. Turkey operations have the highest adoption rates for all farm sales categories except for category $500,000 and above. It is also seen that livestock operations with ruminant species generally have lower adoption rates than the ones with non-ruminant species. In general swine manure is handled as liquid and poultry manure is mostly handled as solid, so it is difficult to explain the higher adoption rates with the type of manure handling system.

Table 23: Adoption Rate of Calibrating Manure Spreaders by Primary Livestock Type of the Operation and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	3.1%	17.2%	8.3%	15.8%	16.7%	26.3%
$100,000-$249,999	9.1%	14.9%	2.9%	38.2%	31.3%	40.7%
$250,000 - $499,999	13.5%	21.9%	14.3%	40.0%	43.8%	62.5%
$500,000 +	42.3%	30.6%	40.0%	50.0%	50.0%	28.6%

5.8.7. Record keeping

Figure 18 shows the perceptions of farmers about keeping detailed records on what day, how much and to what field manure was applied. Overall, farmers believe record keeping is a profitable, but time consuming practice, which also improves water quality. There is a considerable number of farmers who neither agree nor disagree that record keeping is complicated.

Figure 18: Perceptions about Keeping Detailed Records on What Day, How Much and to What Field Manure was Applied

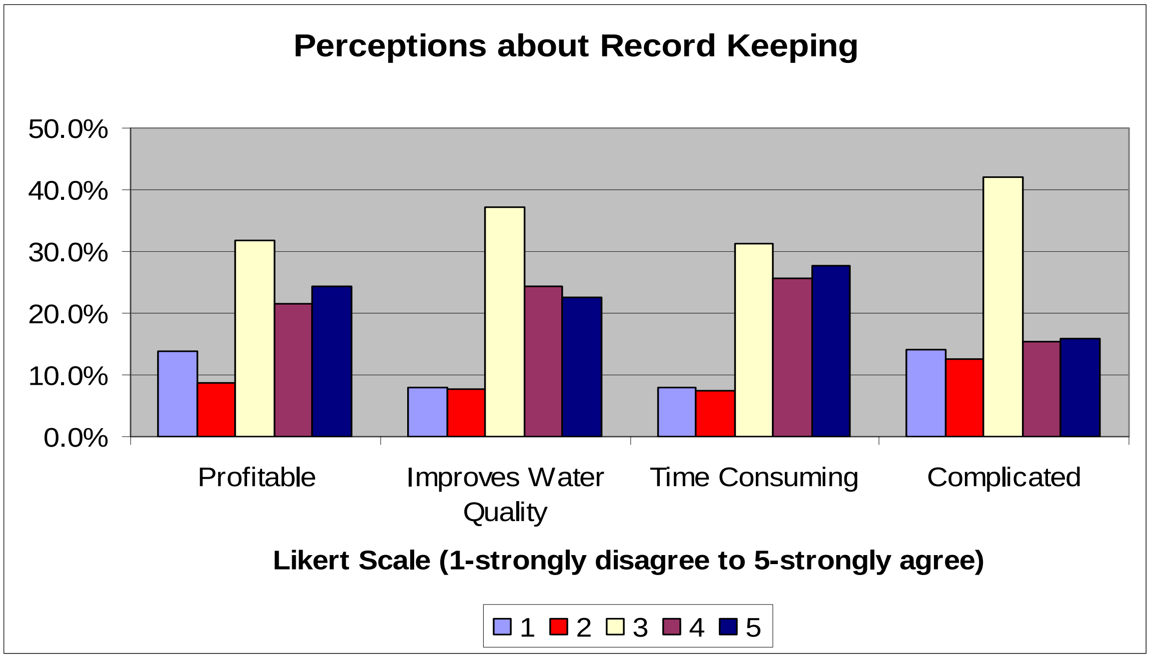


Table 24 shows the adoption rates for keeping detailed records on what day, how much and to what field manure was applied. Swine, broiler and turkey operations have higher adoption rates than dairy cattle, beef cattle and beef cow operations. As the purpose of record keeping is to be able to use the manure at agronomic rates, it is important that farmers who adopt record keeping also calibrate their manure spreaders. The zero adoption rate for the beef cow producers with farm sales of $500,000 and above is probably because these farmers are mostly crop farmers (data not shown).

Table 24: Adoption Rate of Keeping Detailed Records on What Day, How Much and to What Field Manure was Applied by Primary Livestock Type and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	28.21%	21.62%	14.29%	43.18%	33.33%	32.26%
$100,000-$249,999	14.29%	15.38%	9.76%	58.02%	72.00%	57.78%
$250,000 - $499,999	23.26%	21.88%	15.38%	73.91%	64.71%	77.78%
$500,000 +	46.43%	22.50%	0.00%	76.19%	66.67%	57.14%

5.8.8 Grass filters

Figure 19 shows the perceptions of farmers about using a grass filter system as a buffer around water sources. Farmers believe that using a grass filter system is profitable, improves water quality and is not complicated. It is obvious to farmers that this practice improves water quality; very few farmers disagree. There are farmers who believe that this is a time consuming practice, while some other farmers believe the opposite.

Figure 19: Perceptions about Using a Grass Filter System as Buffer around Water Sources

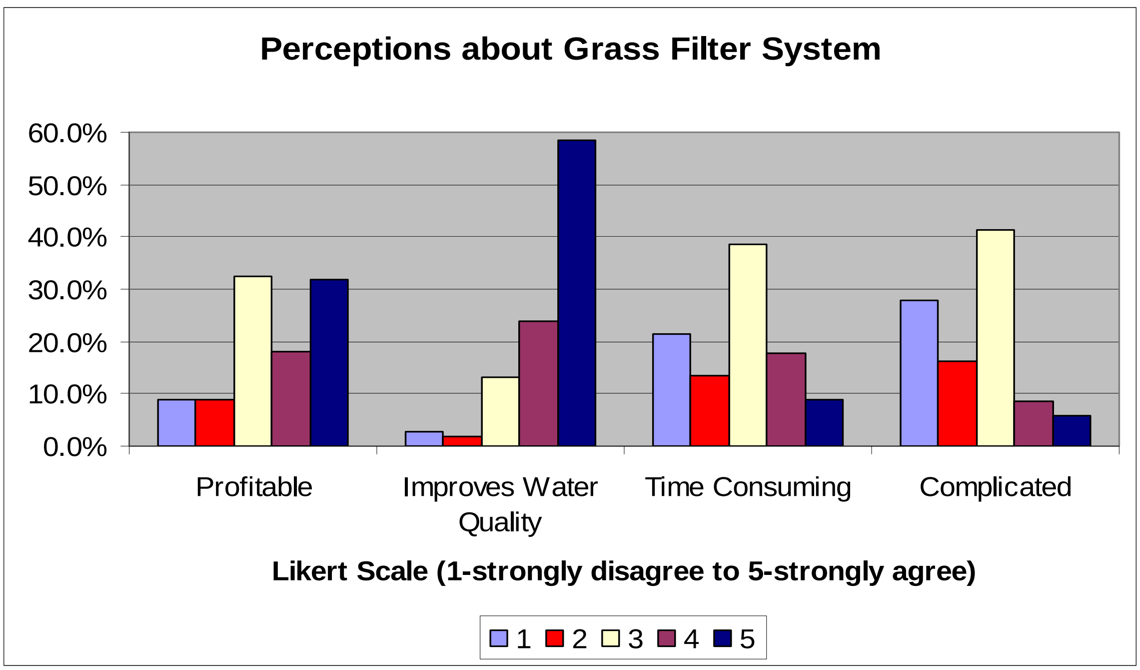


Table 25 shows the adoption rates for using a grass filter system as a buffer around water sources. Adoption rate increases with farm sales for dairy cattle and swine operations. Farms with farm sales of $500,000 and more have the highest adoption rates for all operation types except for beef cattle and turkey operations. It is the case that farms with low farm sales have less crop land, which might cause smaller farms to be less likely to adopt using a grass filter system. This is probably the reason for the zero adoption rate for the broiler operations with the lowest farm sales category.

Table 25: Adoption Rate of Using a Grass Filter System as a Buffer around Water Sources by Primary Livestock Type and Gross Farm Sales (Combined Crop and Livestock Sales)

	Dairy Cattle	Beef Cattle	Beef Cow	Swine	Broiler	Turkey
$10,000 - $99,999	54.6%	51.9%	60.5%	57.9%	0.0%	50.0%
$100,000-$249,999	61.4%	56.3%	65.7%	66.7%	82.4%	58.1%
$250,000 - $499,999	61.5%	78.8%	50.0%	69.2%	75.0%	57.1%
$500,000 +	78.3%	76.3%	80.0%	86.8%	100.0%	42.9%

5.9. Influence of Government Organizations

For policy makers it is important to know which information sources most impact agricultural production decisions of farmers. As existence of a new technology or a practice is diffused by information, knowing the sources of information that farmers use is critical for policy makers to reach and encourage farmers to adopt nutrient management practices.

Figures 20-23 show the impact of banking /lending institutions, contractors / integrators, university and NRCS on the farmer's agricultural production decisions, respectively. Overall, it seems that not many farmers are influenced by these organizations when they make production decisions. This is not in line with the expectation that university and NRCS would have impact on the farmers' decisions. However, Extension was not specifically listed so some farmers may not have made the link from Extension to University. NRCS seemed to have more influence than bankers or contractors.

Figure 20: How Much Influence Do Banking / Landing Institutions Have on the Farmer's Agricultural Production Decisions

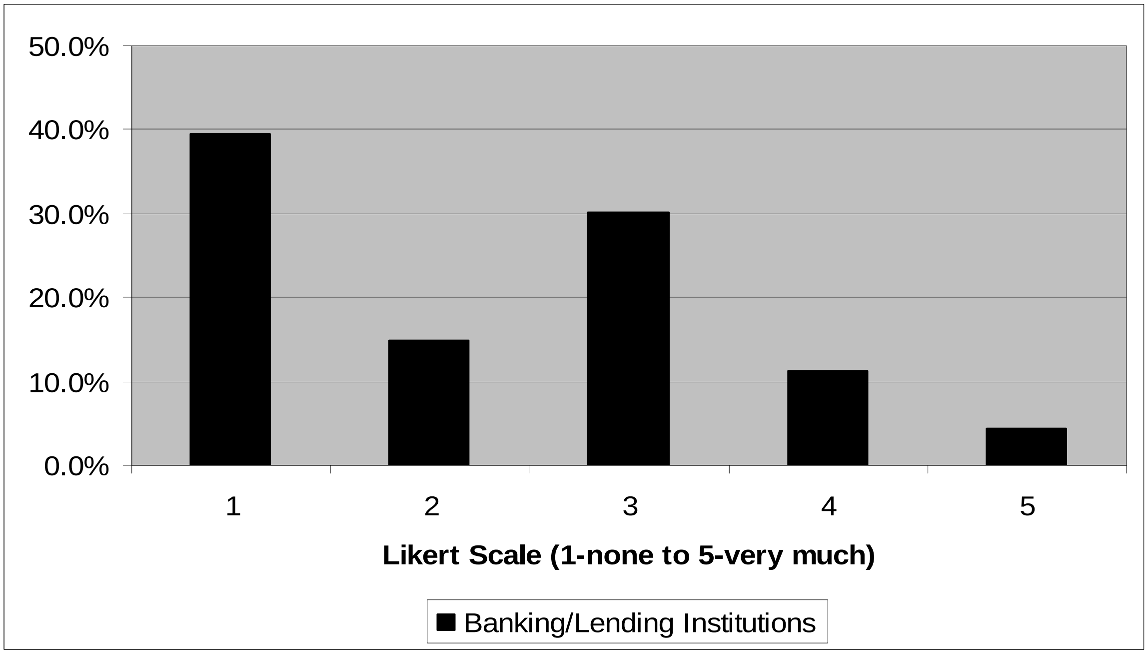


Figure 21: How Much Influence Do Contractors / Integrators Have on the Farmer's Agricultural Production Decisions

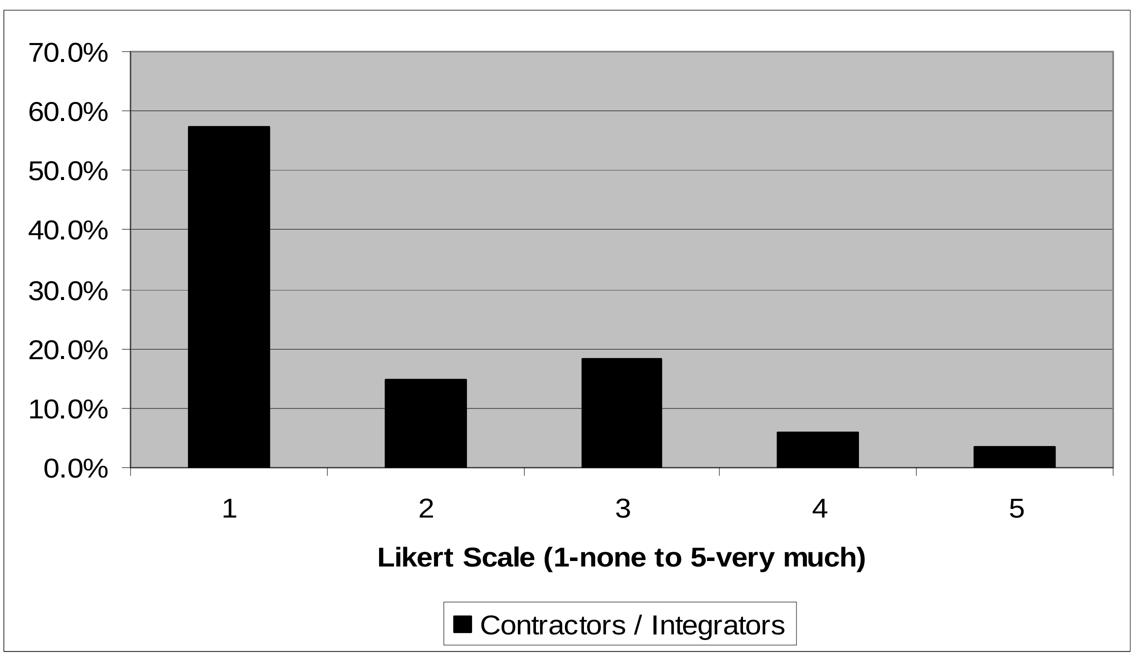


Figure 22: How Much Influence Does the University Have on the Farmer's Agricultural Production Decisions

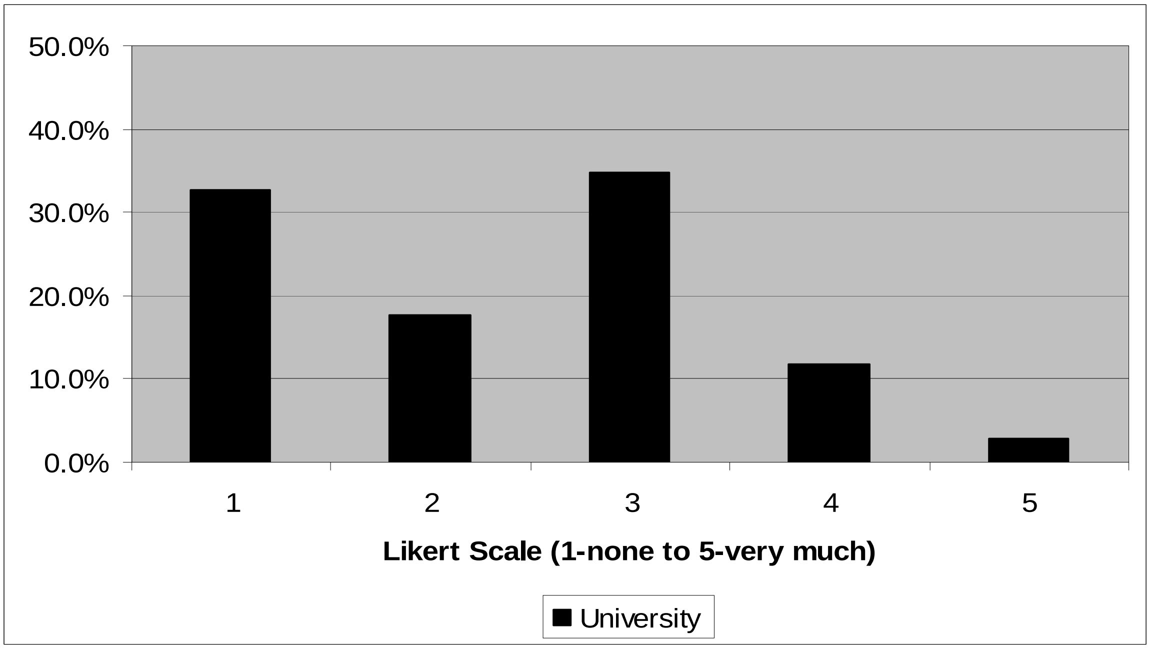
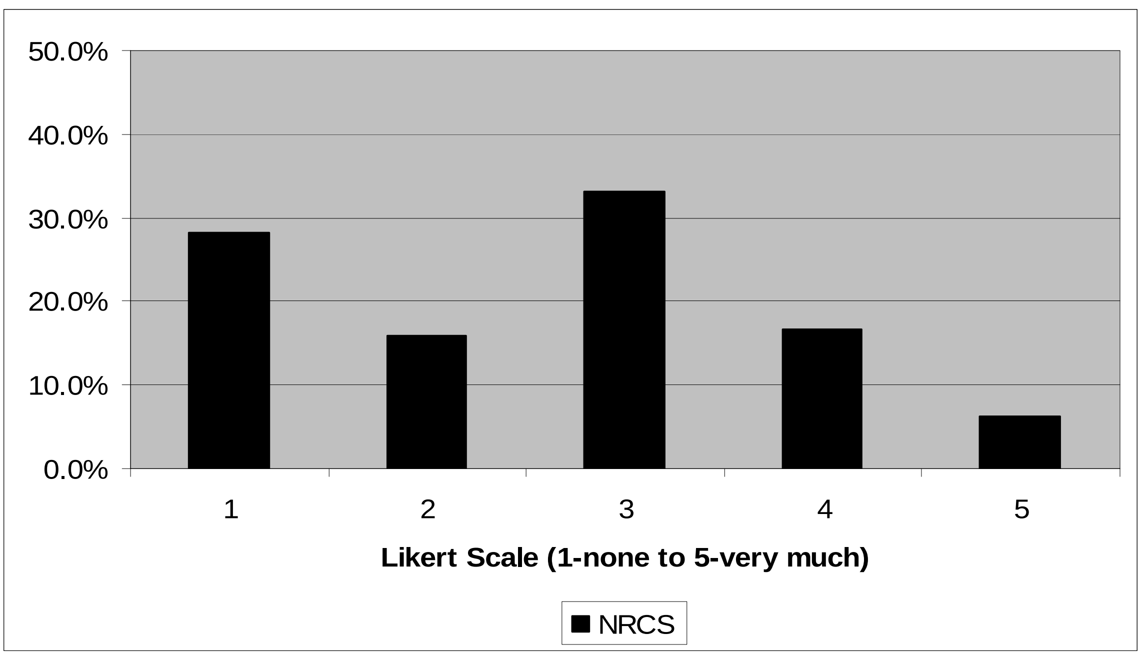


Figure 23: How Much Influence Does NRCS Have on the Farmer's Agricultural Production Decisions



5.10. Implications for Extension

Some implications of the findings from the data set for better extension and water quality policies are addressed below.

What is clear is that one size does not fit all and that the diversity of farming systems poses challenges for programs to improve water quality. Not all practices are appropriate or necessary for all farms. In line with the theory presented in the literature review, in general, larger farms are more likely to adopt the various manure management practices examined by this research. This is true not only for practices that would be expected to exhibit increasing returns to scale but also for scale neutral practices such as soil testing. Getting smaller farmers (many of whom have off-farm jobs) to attend programs, read literature, etc. will be more difficult than dealing with a smaller number of large farms, but this may be worthwhile, especially for scale neutral practices.

5.10.1. Type of the manure handling system

Larger animal feeding operations are less likely to have solid only manure handling systems. Therefore, injecting manure into soil can be targeted to larger operations. This is also a practice that will exhibit economies of scale due to the investment required and this is another reason to focus efforts on larger operations. As more operations move to liquid manure handling systems, we would expect adoption of this practice to increase.

5.10.2. Perceptions and adoption rates

Farmers have neutral perceptions / beliefs about manure testing. More information is needed from extension programs about the benefits of manure testing, especially under conditions of higher fertilizer prices. While adoption rates for soil testing are generally high, smaller farms are less likely to adopt soil testing and there are farmers who are neutral regarding perceptions about time consumption and complexity of soil testing. Hence, smaller farms should be targeted for increasing knowledge about, and adoption of, soil testing. More farmers need to be aware that soil testing and manure testing should be adopted together for best results since many farmers who realize the benefits of soil testing (e.g. farms with large crop acreage) have not yet adopted manure testing. Farmers tend to have neutral perceptions / beliefs about calibrating manure spreaders as well as low adoption rates. Again, it needs to be adopted in conjunction with soil testing and manure testing to both be profitable and to improve water quality. Extension efforts that build on the positive perceptions of soil testing may increase adoption of these related practices.

The finding that practices with low adoption rates typically have a large number of farmers indicating neutral perceptions indicates that more information is needed but that there is not significant misinformation to overcome. As far as perceptions regarding being complicated and time consuming, on-farm demonstrations may be helpful in reducing uncertainty. However, the significant numbers of small farmers with off-farm jobs implies that educational programs need to be flexible as to how and when information is presented. As broad-band internet access expands in rural areas, perhaps video recordings of on-farm demonstrations could be made available to assist this audience.

5.10.3. Influence of government organizations

Farmers indicated that the university, NRCS and banking institutions have little impact on their decisions about the agricultural production. This indicates that farmers are more affected by their own experiences and / or information from other farmers and this is another reason that on-farm demonstrations may be helpful.

CHAPTER 6: OFF-FARM WORK

6.1. Introduction

In this chapter, the impact of off-farm work on adoption of nutrient management practices will be analyzed. The increasing importance of off-farm income for farm families and the results of previous studies about the impact of farm income on adoption of new technologies were examined in the literature review chapter. As mentioned in that chapter, off-farm work can have two different impacts on adoption of a new technology: 1) farmers with off-farm income have more financial capability to adopt new technologies, 2) farmers with off-farm income have less time to adopt new technologies. Hence, depending on capital and time requirements of the technology, off-farm income can be a factor that intensifies adoption or a factor that defers adoption. Descriptions of the technologies were presented in chapter 2.

In the next section a behavioral model that represents the impact of off-farm work on adoption of a new technology will be developed. The empirical model is developed in the methods section. The chapter concludes with results and discussion sections.

6.2. Conceptual Framework

To represent the household's voluntary decision regarding technology adoption, a household utility maximization model is constructed. The current model is extension of the agricultural household models by Huffman (1980) and Cornejo, *et al*. (2005).

The household problem can be represented as;

$$(1) \quad \max_{C, L_e, L_a, K_a} U\left(C, L_e, E(L_a, K_a)\right)$$

$s.t.$

$$(2) \quad P_c.C + r.K + r.K_a + W.L_{on} \leq P_q.Q + W.L_{of}$$

$$(3) \quad L_{on} + L_{of} + L_a + L_e \leq 24$$

$$(4) \quad Q \leq F(K, L_{on})$$

where, U (.) is the utility function of the household, C is the consumption, L_e is leisure, and E(.) is the level of environmental quality, which is an increasing function of amount of labor, L_a, and amount of capital, K_a, reserved for adoption of conservation practices.

The budget constraint is represented in equation (2). P_c is the price of the consumption good, P_q is the price of the farm output, Q is the farm output, W is the wage rate for the off-farm work, r is the market interest rate and K is the capital for production activities. The time constraint is represented in equation (3). The total amount of time available for the farmer is 24 hours. L_{on} is the amount of time provided for on-farm activities, L_{of} is the time devoted to off-farm work. For the current model both on-farm labor and off-farm labor are exogenous to model, to reflect the situation that labor devoted to adoption of new conservation technologies is determined after on-farm and off-farm labor decisions are made. Another type of the model would be the one in which level of time devoted for on-farm activities, off-farm work and for adoption of conservation practices are determined simultaneously, i.e. all of the three variables become endogenous to the model. However, this would not be an appropriate model for the practices that are analyzed in this study, as none of these practices directly impact the revenue of the farm or the income of the farmers. Hence, these practices would require time and capital that would not increase the income for the farmer. This would then imply the farmer first devotes the time for the activities that create income, which are the off-farm work and on-farm activities. For this reason, the time devoted for off-farm work and on-farm activities are assumed to be exogenous to the model.

The technology constraint is reflected in equation (4), *F*(.) is the neo-classical production function, which is an increasing function of amount of capital K, and amount of on-farm labor, L_{on}. To maximize consumption, farmers will always produce at the level available by the technology; hence the technology constraint is always binding; $Q = F(.)$.

To find the solution to the household problem, the structured Langrangian becomes;

$$L: \max_{C, L_e, L_a, K_a} U\big(C, L_e, E(L_a, K_a)\big) + \lambda\big(P_q.F(K, L_{on}) + W.L_{of} - P_c.C - r.K - r.K_a - W.L_{on}\big) + \mu\big(24 - L_{on} - L_{of} - L_a - L_e\big)$$

and the first order conditions become;

(5) $\dfrac{\partial L}{\partial C} : U_1' - P\lambda \leq 0 \qquad C^* \geq 0$

(6) $\dfrac{\partial L}{\partial L_e} : U_2' - \mu \leq 0 \qquad L_e^* \geq 0$

(7) $\dfrac{\partial L}{\partial L_a} : U_3' \dfrac{\partial E(.)}{\partial L_a} - \mu \leq 0 \qquad L_a^* \geq 0$

(8) $\dfrac{\partial L}{\partial K_a} : U_3' \dfrac{\partial E(.)}{\partial K_a} - r\lambda \leq 0 \qquad K_a^* \geq 0$

(9) $\lambda\left(P_q.F(K,L_{on})+W.L_{of}-P_c.C-r.K-r.K_a-W.L_{on}\right)=0$

(10) $\mu\left(24-L_{on}-L_{of}-L_a-L_e\right)=0$

where equations (5)-(8) are the first order conditions for consumption, leisure, labor and capital for adoption of new technology. Equations (9) and (10) reflect that either the constraints hold with equality, hence the insides of the parentheses equal zero and the Langrangian multipliers λ and μ are non-zero, or the Langrangian multipliers are zero and the insides of the parentheses are positive. C^*, L_e^*, L_a^*, K_a^* are the optimal decision variables. U_1', U_2', U_3' represent first order partial derivatives of the utility function with respect to consumption, leisure and environmental quality.

The use of a neoclassical utility function that satisfies the Inada conditions, such as the logarithmic utility function, will lead equation (5) and (6) to hold with equality.[5] Hence, the values of the Langrangian multipliers λ and μ are; $\lambda=\dfrac{U_1'}{P_c}$, $\mu=U_2'$.

The impact of off-farm income on adoption of two types of technologies; labor intensive and capital intensive are analyzed in two different cases.

6.2.1. Labor intensive technology

In this case we assume there is a positive critical amount of labor, L_a^C, that is required by the new technology. Hence, the necessary condition for a farmer to adopt the labor intensive new technology is L_a^* to be at least as large as the critical amount of labor

[5] The Inada condition states that the marginal utility approaches infinity as the choice variable approaches zero, which guarantees an interior solution.

required by the new technology. To show the impact of off-farm income on L_a^* we look at the case where only the time constraint is binding. Using $\mu = U_2'$, the first order condition (6) of L_a^* for an interior solution becomes[6];

$$(11)\quad U_3' \frac{\partial E(.)}{\partial L_a} = U_2' \qquad L_a^* > 0$$

Equation (11) states that, at the optimum, the marginal utility from environmental quality will be equal to the marginal utility from leisure. To find the impact of off-farm income on the amount of labor devoted to adoption, we take the derivative of (11) and as only the time constraint is binding, only L_a^* are L_e^* assumed to be implicitly functions of L_{of} ;

$$(12)\quad U_3''\left(\frac{\partial E(.)}{\partial L_a}\right)^2 \frac{dL_a^*}{dL_{of}} + U_3' \frac{\partial^2 E(.)}{\partial L_a^2} \frac{dL_a^*}{dL_{of}} - U_2' \frac{dL_e}{dL_{of}} = 0$$

which leads to

$$(13)\quad \frac{dL_a^*}{dL_{of}} = \frac{U_2'' \dfrac{dL_e}{dL_{of}}}{U_3''\left(\dfrac{\partial E(.)}{\partial L_a}\right)^2 + U_3' \dfrac{\partial^2 E(.)}{\partial L_a^2}} < 0$$

Hence, as amount of off-farm work increases, the farmer devotes less labor to adoption of a new technology, hence decreasing the probability that the new technology is adopted. In the above equation, using the strict concavity of the utility function and the environmental quality function; the second derivatives of the utility function and the

[6] Even an interior solution may not mean adoption as the solution may still be less than the critical value of the labor required by the new technology. Similar results can be obtained for a corner solution.

environmental quality function are strictly negative, making the denominator negative. The sign of $\frac{dL_e}{dL_{of}}$ is positive due to the binding time constraint; hence the numerator is positive, making the total effect of off-farm work on L_a^* negative.

6.2.2. Capital intensive technology

In this case we assume there is a positive critical amount of capital, K_a^C, that is required by the new technology. Hence, the necessary condition for a farmer to adopt the capital intensive new technology is K_a^* to be at least as large as the critical amount of capital required by the new technology. To show the impact of off-farm income on K_a^* we look to the case where only the budget constraint is binding. Using $\lambda = \frac{U_1'}{P_c}$, the first order condition (8) of K_a^* for an interior solution becomes;

$$(14)\quad U_3' \frac{\partial E(.)}{\partial K_a} = \frac{U_1'}{P_c} r \qquad K_a^* > 0$$

Equation (14) states that, at the optimum, the marginal utility from environmental quality will be equal to the marginal utility from consumption. To find the impact of off-farm income on the amount of capital devoted to adoption, we take the derivative of (14) and as only the budget constraint is binding, only K_a^* and C^* are assumed to be implicitly functions of L_{of};

$$(15)\quad U_3''\left(\frac{\partial E(.)}{\partial K_a}\right)^2 \frac{dK_a^*}{dL_{of}} + U_3' \frac{\partial^2 E(.)}{\partial K_a^2} \frac{dK_a^*}{dL_{of}} - U_1' \frac{r}{P_c} \frac{dC}{dL_{of}} = 0$$

which leads to:

$$(16)\quad \frac{dK_a^*}{dL_{of}} = \frac{U_1'' \frac{r}{P_c} \frac{dC}{dL_{of}}}{U_3''\left(\frac{\partial E(.)}{\partial K_a}\right)^2 + U_3' \frac{\partial^2 E(.)}{\partial K_a^2}} > 0$$

Hence, as the amount of off-farm work increases, the farmer devotes more capital to adoption of the new technology, hence increasing the probability a new technology will be adopted. In the above equation, using the strict concavity of the utility function and the environmental quality function; the second derivatives of the utility function and the environmental quality function are strictly negative, making the denominator negative. The sign of $\frac{dC}{dL_{of}}$ is positive due to the binding time constraint; hence the numerator is also negative, making the total effect of off-farm work on K_a^* negative.

The model leads to empirical hypotheses that will be tested using the data from the survey of Iowa and Missouri livestock farmers;

1. If the new technology is labor intensive, farmers with off-farm work are less likely to adopt the technology than farmers who do not have off-farm work.
2. If the new technology is capital intensive, farmers with off-farm work are more likely to adopt the technology than farmers who do not have off-farm work.

To test hypotheses (1) and (2), the multivariate probit model will be used.

6.3. Methods

In the current study, the producers who have a comprehensive nutrient management plan are expected to jointly adopt practices such as injecting manure into soil, soil testing, grass filters and record keeping. Hence, adoption decisions for the practices are expected to be correlated. Previous studies by Dorfman (1996), Wozniak (1984) and Khanna (2001) have used bivariate and multivariate probit models to analyze the adoption of inter-related technologies. In the current study, the multivariate probit model that is explained in methods chapter is used.

For the empirical model, the adoption decision that farmers make for the practices can be represented as an extension of the theoretical model discussed in the analytical framework. After farmers make their optimal choices of the choice variables; C^*, L_e^*, L_a^*, K_a^*, the utility gained by optimal choice variables is compared to the utility gained by choosing the critical values L_a^C and K_a^C, respectively for labor intensive and capital intensive practices. If the utility gained by the optimal choices is greater than or equal to the utility from the critical value, then the farmer adopts the practice. It is also assumed that the maximized utility has a random factor, ε, which is assumed to have a normal distribution. The maximized utility function is also assumed to be impacted by fixed factors such as age, education, perceptions and so on. These factors are represented by $\mathbf{Z}$, which is a vector, in the maximized utility function.

For a labor intensive technology;

If $\mathrm{U}\left(C^{*}, L_e^{*}, E(L_a{}^{*}, K_a{}^{*}), \mathbf{Z}, \varepsilon\right) \geq \mathrm{U}\left(C^{*}, L_e^{*}, E(L_c\ \ , K_a{}^{*}), \mathbf{Z}, \varepsilon\right)$ then the technology is adopted and

if $\mathrm{U}\left(C^{*}, L_e^{*}, E(L_a{}^{*}, K_a{}^{*}), \mathbf{Z}, \varepsilon\right) < \mathrm{U}\left(C^{*}, L_e^{*}, E(L_c\ \ , K_a{}^{*}), \mathbf{Z}, \varepsilon\right)$ then the technology is not adopted. Hence,

$$y_i = 1 \quad \text{if } U(L_a^{*};) \geq U(L_c;)$$

$$y_i = 0 \quad \text{if } U(L_a^{*};) < U(L_c;)$$

For a capital intensive technology;

if $\mathrm{U}\left(C^{*}, L_e^{*}, E(L_a{}^{*}, K_a{}^{*}), \mathbf{Z}, \varepsilon\right) \geq \mathrm{U}\left(C^{*}, L_e^{*}, E(L_a{}^{*}, K_c\ \ ), \mathbf{Z}, \varepsilon\right)$ then the technology is adopted and

if $\mathrm{U}\left(C^{*}, L_e^{*}, E(L_a{}^{*}, K_a{}^{*}), \mathbf{Z}, \varepsilon\right) < \mathrm{U}\left(C^{*}, L_e^{*}, E(L_a{}^{*}, K_c\ \ ), \mathbf{Z}, \varepsilon\right)$ then the technology is not adopted.

Hence;

$$y_i = 1 \quad \text{if } U(K_a^{*};) \geq U(K_c;)$$

$$y_i = 0 \quad \text{if } U(K_a^{*};) < U(K_c;)$$

6.4. Regression Results and Discussion

The four practices that are used as dependent variables in the regression analysis are: injecting manure into the soil, using a grass filter system as a buffer around water sources, testing soil for nutrients at least every three years, and keeping detailed records on what day, how much and to what field manure was applied. These practices are classified in terms of capital and labor intensity: injecting manure into the soil is capital intensive, using a grass filter system is intermediate, soil testing is neither capital nor labor intensive, and record keeping is labor intensive.

Multicollinearity for the regression variables is checked using the variance inflation factor (VIF). The results are represented in figure 29. The rule of thumb is to further investigate variables for which VIF is greater than 10 (Chen *et. al*., 2003). The only variables that had VIF greater than that were age and age squared. Since age squared is derived directly from age, this result is natural. For the rest of the variables, all the VIF values were less than 10. This shows that multicollinearity did not exist in the regression.

For overall significance of the multivariate probit regression, the p-value for Wald test statistic is equal to 0.00, which shows that the multivariate probit regression is very significant overall. The multivariate probit regression results are given in table 26. Results form univariate probit version of the multivariate probit regression model are presented in table 34 in appendix B. Some of the significant variables found in the multivariate probit regression model are discussed below.

6.4.1. Age

Age represents the experience and innovativeness of the farmer, and also captures differences in the present value of future income between younger and older farmers. The empirical results of previous studies show both positive and negative relationships between age and adoption of new technology. In the current study, age in years has a negative and significant effect on adoption of a grass filter system and soil testing. Age squared is significant and positive for these practices, showing that this effect diminishes. Age is not significant for injecting manure and record keeping. Thus, for practices that are either capital intensive or time intensive it is seen that factors other than age can be more important for adoption. It could be also that younger farmers are more concerned or more knowledgeable about the environment, hence more likely to adopt grass filters.

6.4.2. Education

In the current study, farmers with less than a high school education are less likely to inject manure than farmers with a high school education. Also in line with the literature, farmers with a bachelor's degree are more likely to inject manure than farmers with a high school degree. However, for grass filters, farmers with less than a high school degree are more likely to adopt than farmers with high school education level. Education is found to be insignificant for soil testing. For record keeping, farmers with some college or a vocational school degree are more likely to adopt than farmers with high school degree. However, farmers with a graduate degree are found to be less likely to adopt than farmers with high school degree.

Finding farmers with less than a high school education to be less likely to adopt a practice than farmers with a high school education is consistent with the literature.

However, finding farmers with graduate degrees to be less likely to adopt record keeping than high school graduates requires further investigation. There were 8 farmers in the data set that had graduate degrees and only one of them adopted record keeping. It was suspected that for farmers with graduate education, farming would not be their primary occupation. Hence, the farmers would not adopt record keeping as it is a time intensive practice. However, two of the farmers had farm sales of $10,000-$99,000, four farmers had farm sales of $100,000-$249,999, one of which adopted record keeping, one farmer had farm sales of $250,000-$499,999, and one farmer had farm sales of $500,000 or more. This showed that for some of these farmers, farming could well be the primary occupation. Out of these eight farmers, 5 had year-round off-farm work and none of the farmers had seasonal off-farm work. Two of the farmers who had year-round off-farm work were the ones who had farm sales of $10,000-$99,000. These two farmers also agreed that record keeping is time consuming. These two farmers provide evidence that farmers with a graduate degree and with regular off-farm work did not have farming as their primary occupation and as they thought record keeping was time consuming, they did not adopt record keeping. However, there are also farmers who had no off-farm work and farm sales of $100,000-$249,999 and $500,000 or more and who disagreed that record keeping is time consuming that did not adopt record keeping. Overall, there is still a need for further research to learn why the farmers with a graduate degree are less likely to adopt record keeping. What this study provides is the evidence that there might be some practices for which adoption may not increase with education levels above high school and may even decrease. Also, it could be that education is more important for practices that are complicated or new.

6.4.3. Off-Farm income

In the current study, contrary to expectations, farmers with no off-farm income were not more or less likely to adopt any practice than those with the base off-farm income category ($10,000-$24,999). Farmers with an off-farm income level of $0-$9,999 are found to be more likely to inject manure than farmers with an off-farm income level of $10,000-$24,999. For this capital-intensive practice, off-farm income did not have the expected effect. Both types of farmers indicated that injecting manure is time consuming. Also, farmers with higher off-farm income levels indicated that their spouses have year round off-farm work. It could be the fact that the farmers with higher off-farm income would need extra labor to adopt injecting manure and their spouses can not help them as they have year round off-farm work. More generally, the effect of type of off-farm income does fit with our hypothesis as discussed later in this section.

For grass filters, farmers with off-farm income levels of $0-$9,999 and $25,000-$49,999 are found to be less likely to adopt than farmers with an off-farm income level of $10,000-$24,999. For soil testing, farmers with an off-farm income level of $100,000 and more are found to be less likely to adopt than farmers with off-farm income level of $10,000-$24,999. For record keeping, there is no statistically significant difference between the base category and any of the other off-farm income levels, *ceteris paribus*.

6.4.4. Type of off-farm work

In the current study, it is found that if the farm operator has seasonal off-farm work, then the farmer is more likely to adopt injecting manure and testing soil than a farmer who has no off-farm work. There are more farmers with seasonal off-farm work than farmers with no seasonal off-farm work that have a solid manure handling system, which would explain adoption of soil testing. Having seasonal off-farm work and a solid manure handling system may indicate that these farmers are probably primarily crop farmers. Since knowing the nutrient content of soil is important for crop farmers for yield purposes and also to measure the amount of fertilizer required, they are more likely to adopt soil testing. For the farmers with only liquid or both liquid and solid manure handling systems, having seasonal off-farm work would provide the extra income that is necessary to adopt injecting manure. It is also found that if the farm operator has year round off-farm work, the farmer is more likely to adopt injecting manure than a farmer who has no off-farm work. For grass filters and record keeping, having off-farm work is found to be insignificant.

Comparison of the regression results with the behavioral model predictions reveals that there is support for the behavioral model predictions for the case of injecting manure. Hence, the results provide evidence that adoption of a capital intensive practice is positively impacted by the off-farm work of the farmer. However, the regression results do not provide evidence for the hypothesis that adoption of a labor intensive technology is negatively impacted by the off-farm work of the farmer.

A spouse's off-farm work is associated with extra income creation and less contribution to farm work. Hence, it is expected to have a positive impact on adoption of capital intensive technologies and a negative impact on labor intensive technologies. Farms with lower farm acreage and farm sales are more likely to have the spouse work off the farm. If the spouse of the farmer has seasonal off-farm work, then the farmer is significantly less likely to adopt injecting manure but significantly more likely to adopt testing soil. Also, if the spouse of the farmer has year round off-farm work, then the farmer is more likely to adopt soil testing. For injecting manure the result that spouse's off-farm work decreases adoption is further investigated. When the acres per animal unit is investigated, it is seen that farmers that adopted injecting manure had fewer acres per animal unit than farmers that did not adopt injecting manure. It is also found that farmers whose spouse has seasonal off-farm work have lower acres per animal unit. Hence, these farmers might prefer to adopt injecting manure as less land would cause run-off of the manure if it was surface applied. However, as farmers indicated that injecting manure takes time, the farmers might not have labor available to inject manure if their spouses work during the period when manure is injected into the fields. More research is needed to explain the effect of the spouse's off-farm work. For example, no information was obtained on the motivation for off farm work (income, health insurance, career goals) or the timing of seasonal work. As far as we know, this is the first adoption study to examine the effect of the spouse's work, separate from household off-farm income level.

6.4.5. Farm sales

In the current study, farmers with farm sales of $10,000-$99,999 are found to be less likely to adopt injecting manure, grass filters and soil testing than farmers with farm sales of $100,000-$249,999. Farmers with farm sales of $500,000 and more are found to be more likely to adopt injecting manure and grass filters than farmers with farm sales of $100,000-$249,999. For record keeping, there is no significant difference between the base category and other categories of farm sales. Finding farmers with higher farm sales to be more likely to adopt injecting manure shows that there is economies of scale for this practice. Finding larger farmers to be more likely to adopt grass filters is in line with the literature.

6.4.6. Environmental perceptions

In the current study, it is found that farmers that disagreed with the statement that the smell of manure bothers me or my family are more likely to inject manure but less likely to adopt testing soil than farmers who agreed with the statement. If the smell of manure does not bother the farmer's neighbor, the farmer is less likely to adopt injecting manure. In other words, farmers may inject manure in order to not bother their neighbors. If the farmer is not unsure about how his / her crops would respond to manure as compared to commercial fertilizer, then the farmer is more likely to adopt soil testing. For all four practices, there is no statistically significant difference between farmers who are not concerned about the about the water quality of streams and lakes in the farmers' counties and those who are. This situation is also valid for the statement that properly managing manure improves water quality. If the farmer disagrees that agricultural regulations regarding water quality will become stricter in the next five years, the farmer is less likely to adopt injecting manure. In other words, those farmers who expect regulations to be more strict may be more likely to make investments in equipment related to environmental quality. If a farmer disagrees with the statement that transportation costs and time affect which of the farmer's fields receive manure, the farmer is more likely to adopt soil testing and record keeping than a farmer who agrees with the statement. They may be more likely to view the manure as a fertilizer resource rather than a waste product.

6.4.7. Perceptions about the practices

In the current study it is found that there is a statistically significant and positive relationship between perceived profitability of the practices and their adoption. If a farmer disagrees that the practice is profitable, the farmer is less likely to adopt injecting manure, grass filters, soil testing and record keeping. For injecting manure, if the farmers disagree that the practice improves water quality, then the farmer is less likely to adopt than farmers who agree with the statement. For grass filters and record keeping, farmers that are neutral towards the statement that the practice improves water quality are less likely to adopt than farmers who agree with the statement. For soil testing, the farmers who disagree with the statement that the practice improves water quality are more likely to adopt than farmers who agree with the statement. Specific knowledge about the relationship between a practice and water quality seems to be a better predictor of adoption than general statements regarding environmental attitudes but, while soil testing does have positive environmental impacts, it is not adopted for that reason. Being time consuming is not significant for injecting manure and grass filters. Farmers who are neutral regarding whether soil testing is time consuming are more likely to test than those who agree with the statement. Farmers that disagree that record keeping is time consuming are more likely to adopt than farmers who agree. Being complicated is found significant for injecting manure, grass filters and soil testing. For all three practices, if a farmer disagrees that the practice is complicated, then the farmer is more likely to adopt the practice.

6.4.8. Environmental Quality Incentives Program (EQIP)

EQIP is a cost share program and it is expected that farmers who have an EQIP contract are more likely to adopt practices that are costly to the farmers. However, it is found that farmers with an EQIP contract are less likely to adopt injecting manure, which is a capital intensive practice. It was found that 54% of the farmers that have an EQIP contract have only a solid manure handling system, which may explain why having an EQIP contract had a negative impact on the adoption of injecting manure.

6.4.9. Manure handling systems

Type of manure handling system is significant for injecting manure and record keeping. Farmers with either only solid manure handling systems or both solid and liquid manure handling systems are less likely to inject manure than farmers with only liquid manure handling systems. As the farmers need liquid manure to adopt injecting manure, the results are consistent with the expectation. Also, farmers with either only solid manure handling systems or both solid and liquid manure handling systems are less likely to adopt record keeping than farmers with only liquid manure handling systems.

6.4.10. Animal units

The total number of livestock on a farm is measured by animal units. The results show the more livestock a farmer has on the farm, the more likely it is that the farmer adopts soil testing and record keeping. This shows that as the amount of manure that should be handled and land applied increases, farmers are more likely to test the soil and keep records. This may be because the potential for excess nutrients is higher. However, we would have expected a positive relationship between animal units and injecting manure since there are economies of scale involved with that practice.

6.4.11. Species

Type of livestock operation is represented by the species. It is seen that the type of livestock operation is most important for injecting manure and record keeping. Dairy cattle, beef cow and poultry operations are less likely to adopt injecting manure than swine operations. As swine manure is mostly handled as liquid, this result is expected. Swine manure is also perceived to have more of an odor problem. Beef cattle operations are more likely to adopt soil testing but less likely to adopt record keeping than swine operations. Beef cow operations are also more likely to adopt soil testing than swine operations. It is found that beef cattle and beef cow operations have more crop production than swine operations, which encourages soil testing to reduce excess commercial fertilizer applications. Turkey operations are more likely to adopt record keeping than swine operations. For grass filters, none of the species are significant.

6.4.12. Correlation among adoption of practices

Table 27 shows the correlation among adoption of the practices. The p-value for overall significance of the correlation matrix is 0.00, which also supports the use of multivariate probit regression instead of univariate probit regression. There is a positive (30%) and significant correlation between adoption of grass filters and soil testing. This shows that farmers who adopt grass filters are more likely to adopt soil testing. The correlation between soil testing and record keeping is also positive (27%) and significant. These correlations can show how the policies to increase adoption of one practice can impact the adoption another practice.

6.4.13. Marginal effects

To find the partial effect of a variable on the probability of adoption of a practice, marginal effects are calculated following Wooldridge (2006) and shown in table 28. Following Wooldridge (2006), the partial (marginal) effect of a variable on the probability of adopting a practice can be calculated for a continuous independent variable as;

$$\mathrm{P}(\mathrm{y}=1|\mathrm{x}_1,\mathrm{x}_2,...,\mathrm{x}_\mathrm{k}) = \mathrm{G}(\mathbf{XB})$$

Where $\mathrm{P}(\mathrm{y}=1|\mathrm{x}_1,\mathrm{x}_2,...,\mathrm{x}_\mathrm{k})$ is the probability of adopting a practice given the explanatory variables $x_1, x_2,..., x_k$. G(.) is the cumulative distribution function, which is the standard normal distribution function for the probit model (Greene, 2003). The partial effect of a continuous variable x_j then can be calculated as;

$$\frac{\partial P(y=1|x_1,x_2,...,x_k)}{\partial x_j} = \frac{\partial G(\mathbf{XB})}{\partial x_j} B_j$$

$\frac{\partial \mathrm{G}(\mathbf{XB})}{\partial \mathrm{x}_\mathrm{j}}$ is the probability density function, which is valued at the mean of the independent variables to measure the partial impact an independent variable x_j on the probability of adopting a practice.

For a discrete variable x_j, such as a dummy variable, the partial effect can be calculated following Wooldridge (2006) as;

$$G(B_0 + B_1x_1 + ... + B_j + ... + B_kx_k) - G(B_0 + B_1x_1 + ... + B_kx_k).$$

In the first parenthesis x_j is equal to 1 and in the second parenthesis x_j is equal to zero. An example for this can be given using table 28; probability of adopting injecting manure increases by 0.027 or almost 3% if a farm operator has year round off-farm work.

Some of the marginal effects will be discussed for the significant variables. For injecting manure into soil, farm operator's year round off-farm work, having farm sales of $500,000 or more, disagreeing with the statement that the smell of manure bothers me or my family, and disagreeing with injecting manure is complicated are the most effective variables on adoption.

For grass filters, having farm sales of $500,000 or more, disagreeing with having grass filters is complicated and having only solid manure handling systems are the variables that most effectively increase the probability of adopting the practice. Having education level of less than high school, having off-farm income levels of $0-$9,999 and $25,000-$49,999, and disagreeing it is profitable are the variables that most significantly decrease the probability of adopting the practice.

For soil testing, being a farmer in Iowa, having seasonal off-farm work for both the farm operator and the spouse, disagreeing with not being sure how crops respond to manure as compared to commercial fertilizer, disagreeing with soil testing is complicated and being a primarily beef cow or beef cattle operation are the variables that most increased the probability of adopting the practice. Having off-farm income of $100,000 or more, disagreeing with the smell of manure bothers me or my family, disagreeing with soil testing is profitable are the variables that decrease the probability of adopting the practice the most.

For record keeping, having some college or vocational school level of education and disagreeing with it being time consuming are the variables that increase the probability of adopting the practice the most. Disagreeing with record keeping is profitable, having either only solid manure handling system or both solid and liquid manure handling system, being primarily a beef cow operation are the variables that most decrease the probability of adopting the practices.

Overall, perceptions about the practices and manure handling systems are the most important factors that impact adoption of practices. These results show that policy makers and extension staff should focus on these variables to promote adoption of the practices that are the subject of the current study.

6.5. Conclusion

The recent studies that analyzed adoption of agricultural practices / technologies incorporated off-farm income into their analyses. This was partly due to the increasing share of off-farm income in farmers' total income. Since, the variables that were previously analyzed could not explain the adoption or non-adoption of all the practices / technologies, it was expected that off-farm income could help researchers to explain why some practices were adopted while others were not adopted. However, the results of previous studies showed that having off-farm income does not always lead to adoption of a practice / technology. Some studies found positive and some found negative relationships between having off-farm income and adoption of a practice / technology.

The purpose of the current study is to explain when having off-farm income leads to adoption and when it leads to non-adoption of a practice / technology. Previous studies had off-farm income in their regressions as a dummy variable; have off-farm income or not. This actually causes problem as the off-farm income can be due to farm operator's off-farm work or the spouse's off-farm work. These need to be separated. Type of the off-farm work is also important. Having a seasonal off-farm job may not interfere with crop production, whereas having year-round work would interfere with farming activities. Other important information is the level of off-farm income. It is expected that farmers with high levels of off-farm income may not be primarily farmers, hence may not be willing to adopt some of the agricultural practices.

To incorporate all this information into the analyses, the current study had the farm operator and the spouse as separate and also had seasonal and year-round off-farm work distinguished. The current study also incorporated having different levels of off-farm income into the analysis. Besides finding empirical evidence, it is very important to form a conceptual framework that would explain why off-farm income impacts adoption, otherwise the empirical evidence could be only because of a correlation and could not be used by policy makers to stimulate adoption of practices.

Besides the contradictory empirical results about off-farm income, the previous studies also did not have a conceptual framework which would explain why off-farm income impacts adoption of practices. The current study also contributed to the literature by providing a conceptual framework or a model that explains how having off-farm income impacts adoption of practices. The model that is developed in the current study is based on the fact that having off-farm income would generate extra income but would require time to be taken away from farming activities. Hence, having off-farm would generate extra income that can be used for adoption of a practice that is capital intensive, but would lessen the time that is available to adopt a practice that is time intensive.

Empirical results of the current study provided evidence that adoption of a capital intensive technology is positively impacted by off-farm work. However, the results only partially support the hypotheses for a time intensive practice. Results of the current study reveal that, to measure the impact of off-farm income on adoption of conservation practices it is important to know the capital and labor requirements of these practices. However, there is further research needed to show the impact of off-farm income on adoption of practices that are neither capital nor time intensive. The results of the current study showed that spouse's off-farm work is very important. A future study that included educational level of the spouse can gain more insight about the type of off-farm work of the spouse. Besides, the number of children and their ages should also be included in future research. The main idea is to be able to incorporate additional information about the farm family into the analyses to understand the decision process and constraints.

Besides the off-farm income and work, the current study also provided information that is important for other variables that were incorporated in previous studies. The general wisdom is that adoption of a practice increases as the level of education of farmers increases. The current study provided evidence that there is no linear relationship between adoption and level of education. Having high school graduates be more likely to adopt practices than farmers with education level of less than high school, but having no difference between high school graduates and farmers with education level of higher than high school is evidence for this. Maybe farmers get most of the required knowledge and skill to adopt practices in high school and the knowledge that is obtained in further studies would not impact farmers' decision to adopt a practice / technology. It is also the case that all of these technologies and practices were mature. Education may be more important for new technologies.

Another important finding of the current is study is about perceptions. The general wisdom is that farmers that have positive perceptions or attitudes about conserving the environment or being a steward of the environment, would adopt environmental practices. However, the current study provided evidence that having positive perceptions about conserving the environment is not enough for farmers to adopt most practices. It is found that the perceptions about the practices themselves are more important factors. Hence, extension programs focusing on the specific benefits of the practices (both profitability and water quality) should lead to higher adoption rates of the practices.

The results of the current study showed also that the farming system and specifically the way manure handled is also an important factor that impact adoption of practices. Hence, studies that analyze adoption of certain practices should not only focus on economical or social factors, but also the farming system.

Overall, the importance of off-farm income is expected to increase in the future, and programs and policies to increase the adoption of environmental practices need to take this into account. Time to acquire information and perform practices is increasingly scarce. For farmers with full-time jobs, meeting with NRCS agents during the day is problematic. EQIP and other incentive programs can help capital-constrained farmers but the application process is time-consuming and requires interaction with NRCS agents. In addition, the design of new technologies should take into account the opportunity cost of farmers' time as well as the out of pocket costs.

Table 26: Results of the Multivariate-Probit Regression

Variable	Inject Manure		Grass Filter		Soil Testing		Record Keeping	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Age	0.10	0.31	-0.09	0.05	-0.17	0.01	0.02	0.71
Age^2	0.00	0.20	0.00	0.09	0.00	0.01	0.00	0.62
Iowa	1.08	0.00	0.03	0.85	0.53	0.01	0.22	0.27
Education								
Less than High School	-2.49	0.00	-0.57	0.05	-0.35	0.23	-0.14	0.67
Some College or Vocational School	-0.01	0.98	-0.25	0.12	-0.12	0.53	0.34	0.05
Bachelor Degree	0.59	0.10	-0.08	0.70	0.03	0.89	0.14	0.51
Graduate Degree	-6.11	0.37	-0.10	0.86	0.06	0.92	-6.20	0.00
Off-farm Income								
None	-0.17	0.76	-0.02	0.95	0.46	0.16	0.39	0.24
$0 - $9,999	0.95	0.04	-0.45	0.07	-0.07	0.80	0.41	0.12
$25,000 - $49,999	-0.55	0.23	-0.52	0.02	-0.13	0.61	-0.12	0.59
$50,000 - $99,999	-0.28	0.60	-0.26	0.40	-0.29	0.38	-0.07	0.83
$100,000 +	0.58	0.49	-0.63	0.24	-1.22	0.01	-0.44	0.50
Contributes Significantly to Farm Work								
Spouse	0.18	0.55	-0.16	0.32	-0.20	0.22	-0.08	0.64
Other Family Member	0.41	0.19	0.21	0.15	0.11	0.51	-0.27	0.09
Off-Farm Work								
Farm Operator Seasonal	0.89	0.00	0.17	0.40	0.54	0.06	-0.05	0.80
Farm Operator Year Round	1.41	0.01	0.05	0.84	-0.03	0.91	-0.08	0.76
Spouse Seasonal	-0.89	0.10	0.17	0.60	1.21	0.00	-0.08	0.83
Spouse Year Round	0.16	0.71	0.11	0.64	0.70	0.01	0.12	0.60
Off-farm work interfere								
Yes	-0.33	0.41	0.36	0.11	0.11	0.65	0.15	0.51
Not Applicable	-0.08	0.80	-0.22	0.21	-0.07	0.74	-0.21	0.26
Hire Non-Farm Labor	0.11	0.71	-0.05	0.74	0.17	0.32	0.15	0.33
Farm Sales								
$10,000 - $99,999	-0.92	0.04	-0.36	0.04	-0.37	0.07	-0.04	0.83
$250,000 - $499,999	0.30	0.40	0.14	0.48	0.07	0.76	0.00	0.99
$500,000 +	1.49	0.00	0.54	0.05	0.13	0.68	0.20	0.46
Smell of Manure Bothers Me or My Family								
Disagree	1.28	0.01	-0.25	0.31	-0.67	0.01	0.06	0.82
Neutral	0.26	0.48	-0.25	0.25	-0.43	0.06	-0.11	0.63
Smell of Manure Bothers My Neighbors								
Disagree	-0.98	0.03	0.16	0.50	-0.06	0.81	-0.32	0.22
Neutral	0.48	0.16	0.21	0.27	0.24	0.22	0.06	0.79
Not Sure How Crops Respond to Manure								
Disagree	0.22	0.61	0.20	0.37	0.45	0.08	0.09	0.71
Neutral	0.73	0.11	-0.15	0.55	0.12	0.65	-0.03	0.91

Table 26: Results of the Multivariate-Probit Regression (Continued)

Variable	Inject Manure		Grass Filter		Soil Testing		Record Keeping	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Concerned about the Water Quality								
Disagree	0.61	0.28	0.02	0.95	0.51	0.11	-0.53	0.18
Neutral	0.93	0.04	0.11	0.68	-0.36	0.17	-0.13	0.62
Managing Manure Improves Water Quality								
Disagree	1.08	0.14	0.15	0.74	0.37	0.42	0.59	0.22
Neutral	-0.88	0.10	0.21	0.38	-0.02	0.94	-0.03	0.91
Regulations will be Stricter	-2.06	0.08	-0.18	0.71	0.43	0.26	-0.75	0.29
Disagree								
Neutral	0.59	0.10	0.17	0.38	-0.08	0.67	0.17	0.38
Transportation Costs and Time Affect Which of My Fields Receive Manure								
Disagree	0.16	0.59	0.14	0.39	0.63	0.00	0.39	0.03
Neutral	0.04	0.90	-0.48	0.01	0.33	0.11	0.20	0.37
Continue Farming								
Yes	-1.14	0.09	-0.11	0.77	0.54	0.15	0.42	0.26
Not Sure	0.73	0.30	-0.32	0.45	-0.03	0.95	-0.22	0.66
Expand Livestock Numbers								
Yes	-0.44	0.27	-0.28	0.11	0.30	0.13	-0.12	0.54
Not Sure	-0.59	0.06	-0.14	0.41	0.10	0.64	-0.05	0.78
Profitable								
Disagree	-2.18	0.00	-1.27	0.00	-1.33	0.00	-1.07	0.00
Neutral	-1.73	0.00	-0.91	0.00	-1.25	0.00	-0.53	0.01
Improves Water Quality								
Disagree	-5.77	0.00	-0.04	0.91	0.68	0.09	0.08	0.77
Neutral	-1.3	0.01	-0.67	0.00	-0.13	0.49	-0.43	0.02
Time Consuming								
Disagree	0.30	0.47	0.11	0.64	0.03	0.89	1.03	0.00
Neutral	0.15	0.61	-0.30	0.13	-0.38	0.05	0.40	0.04
Complicated								
Disagree	1.28	0.00	0.50	0.06	0.68	0.01	0.19	0.43
Neutral	0.52	0.23	0.35	0.14	0.35	0.19	-0.02	0.91
EQIP	-1.08	0.01	0.09	0.65	0.22	0.31	0.20	0.30
Manure Handling								
Solid	-3.75	0.00	0.33	0.24	0.11	0.72	-1.28	0.00
Solid and Liquid	-1.05	0.03	0.20	0.46	0.09	0.77	-1.01	0.00
Total Animal Units	0.00	0.55	0.00	0.93	0.00	0.07	0.00	0.04
Species Dummy								
Dairy	-1.02	0.03	-0.24	0.32	0.15	0.57	-0.27	0.31
Beef Cow	-0.52	0.18	-0.25	0.30	0.78	0.00	-0.43	0.10
Beef Cattle	-2.07	0.01	-0.04	0.89	0.67	0.02	-0.49	0.11
Poultry	-1.27	0.08	-0.10	0.80	0.17	0.66	0.51	0.28
Turkey	0.60	0.26	0.04	0.91	0.36	0.35	0.79	0.03
Other	0.05	0.95	0.07	0.91	-0.35	0.55	0.98	0.07
Constant	-1.63	0.56	3.72	0.01	2.93	0.10	-0.58	0.70

Table 27: Correlation among Adoption of Practices

Practices	Correlation Coefficient	P-Value
Inject Manure and Grass Filter	0.18	0.17
Inject Manure and Soil Test	-0.21	0.18
Inject Manure and Record Keeping	-0.02	0.87
Grass Filter and Soil Test	0.15	0.14
Grass Filter and Record Keeping	0.30	0.00
Soil Test and Record Keeping	0.27	0.00
Overall Significance	Chi-Square(6)=19.44	0.00

Table 28: Marginal Effects (dy/dx) for the Multivariate-Probit Regression

Variable	Inject Manure	Grass Filter	Soil Testing	Record Keeping
	dy/dx	dy/dx	dy/dx	dy/dx
Age	0.001	-0.034	-0.048	0.003
Age^2	0.000	0.000	0.000	0.000
Iowa	0.005	0.008	0.159	0.069
Education				
Less than High School	-0.003	-0.215	-0.108	-0.044
Some College or Vocational School	0.000	-0.091	-0.038	0.104
Bachelor Degree	0.006	-0.022	0.009	0.047
Graduate Degree		-0.056	0.026	
Off-farm Income				
None	0.000	-0.005	0.110	0.111
$0 - $9,999	0.012	-0.165	-0.005	0.119
$25,000 - $49,999	-0.002	-0.197	-0.025	-0.026
$50,000 - $99,999	-0.001	-0.082	-0.067	-0.009
$100,000 +	0.006	-0.253	-0.380	-0.089
Contributes Significantly to Farm Work				
Spouse	0.001	-0.064	-0.049	-0.009
Other Family Member	0.002	0.081	0.030	-0.084
Off-Farm Work				
Farm Operator Seasonal	0.004	0.054	0.148	-0.011
Farm Operator Year Round	0.027	0.019	-0.023	-0.033
Spouse Seasonal	-0.002	0.050	0.194	-0.009
Spouse Year Round	0.001	0.037	0.184	0.029
Off-farm work interfere				
Yes	-0.001	0.123	0.042	0.042
Not Applicable	0.000	-0.093	-0.013	-0.061
Hire Non-Farm Labor	0.001	-0.019	0.046	0.047
Farm Sales				
$10,000 - $99,999	-0.002	-0.133	-0.118	-0.009
$250,000 - $499,999	0.002	0.060	0.018	0.003
$500,000 +	0.035	0.190	0.045	0.042
Smell of Manure Bothers Me or My Family				
Disagree	0.011	-0.091	-0.200	0.011
Neutral	0.001	-0.093	-0.130	-0.025
Smell of Manure Bothers My Neighbors				
Disagree	-0.003	0.052	-0.009	-0.069
Neutral	0.003	0.070	0.067	0.005
Not Sure How Crops Respond to Manure				
Disagree	0.001	0.080	0.152	0.046
Neutral	0.00	-0.045	0.050	0.011

Table 28: Marginal Effects (dy/dx) for the Multivariate-Probit Regression (Continued)

Variable	**Inject Manure**	**Grass Filter**	**Soil Testing**	**Record Keeping**
	dy/dx	**dy/dx**	**dy/dx**	**dy/dx**
Concerned about the Water Quality				
Disagree	0.007	0.002	0.109	-0.132
Neutral	0.017	0.037	-0.112	-0.048
Managing Manure Improves Water Quality				
Disagree	0.020	0.073	0.095	0.275
Neutral	-0.001	0.078	-0.001	0.012
Regulations will be Stricter				
Disagree	-0.002	-0.084	0.108	-0.157
Neutral	0.005	0.046	-0.017	0.048
Transportation Costs and Time Affect Which of My Fields Receive Manure				
Disagree	0.001	0.055	0.170	0.097
Neutral	0.000	-0.175	0.089	0.044
Continue Farming				
Yes	-0.017	-0.033	0.165	0.114
Not Sure	0.013	-0.120	-0.011	-0.041
Expand Livestock Numbers				
Yes	-0.002	-0.093	0.079	-0.059
Not Sure	-0.002	-0.046	0.029	-0.026
Profitable				
Disagree				
Neutral	-0.003	-0.473	-0.486	-0.250
Improves Water Quality				
Disagree	-0.010	-0.338	-0.429	-0.155
Neutral	-0.005	-0.001	0.120	0.037
Time Consuming				
Disagree		-0.242	-0.036	-0.116
Neutral	0.003	0.063	0.006	0.330
Complicated				
Disagree	0.001	-0.096	-0.097	0.095
Neutral	0.015	0.166	0.161	0.062
EQIP	0.002	0.120	0.075	0.023
Manure Handling	-0.005	0.031	0.070	0.063
Solid				
Solid and Liquid	-0.229	0.127	0.024	-0.384
Total Animal Units	-0.003	0.075	0.015	-0.234
Species Dummy	0.000	0.000	0.000	0.000
Dairy				
Beef Cow	-0.003	-0.088	0.043	-0.076
Beef Cattle	-0.002	-0.098	0.179	-0.108
Poultry	-0.003	-0.019	0.150	-0.115
Turkey	-0.002	-0.059	0.064	0.140
Other	0.005	0.016	0.074	0.246

Table 29: Multicollinearity Analyses

Variable	Inject Manure	Grass Filter	Soil Testing	Record Keeping
	VIF	VIF	VIF	VIF
Age	58.92	61.62	65.72	61.40
Age^2	58.60	61.72	65.42	61.32
Iowa	2.01	1.87	1.86	1.89
Education	1.99			
Less than High School	1.99	2.00	1.95	2.01
Some College or Vocational School	1.38	1.40	1.36	1.41
Bachelor Degree	1.45	1.48	1.46	1.43
Graduate Degree	1.29	1.30	1.28	1.30
Off-farm Income				
None	3.97	3.99	3.90	3.82
$0 - $9,999	1.91	1.96	1.96	1.93
$25,000 - $49,999	2.23	2.24	2.23	2.26
$50,000 - $99,999	1.87	1.76	1.88	1.86
$100,000 +	1.33	1.37	1.30	1.33
Contributes Significantly to Farm Work				
Spouse	1.41	1.41	1.42	1.41
Other Family Member	1.24	1.28	1.29	1.31
Off-Farm Work				
Farm Operator Seasonal	1.50	1.50	1.51	1.53
Farm Operator Year Round	2.71	2.71	2.72	2.79
Spouse Seasonal	1.59	1.64	1.63	1.63
Spouse Year Round	3.11	3.17	3.05	3.05
Off-farm work interfere				
Yes	2.01	1.97	2.00	2.00
Not Applicable	1.66	1.61	1.63	1.62
Hire Non-Farm Labor	1.25	1.23	1.24	1.25
Farm Sales				
$10,000 - $99,999	1.63	1.64	1.67	1.62
$250,000 - $499,999	1.60	1.63	1.63	1.62
$500,000 +	1.90	1.95	1.96	1.92
Smell of Manure Bothers Me or My Family	1.91	1.97	1.97	1.96
Smell of Manure Bothers My Neighbors	1.81	1.89	1.81	1.80
Not Sure How Crops Respond to Manure	1.42	1.51	1.45	1.41
Concerned about the Water Quality	1.74	1.76	1.67	1.66
Managing Manure Improves Water Quality	1.95	2.01	1.93	1.83
Regulations will be Stricter	1.50	1.54	1.57	1.55

Table 29: Multicollinearity Analyses (Continued)

Variable	Inject Manure	Grass Filter	Soil Testing	Record Keeping
	VIF	VIF	VIF	VIF
Transportation Costs and Time Affect Which of My Fields Receive Manure	1.28	1.35	1.28	1.30
Continue Farming				
Yes	2.95	3.33	3.09	3.12
Not Sure	2.83	3.15	3.01	3.01
Expand Livestock Numbers				
Yes	1.58	1.57	1.58	1.59
Not Sure	1.36	1.38	1.37	1.41
Profitable				
Improves Water Quality	1.98	1.71	1.37	2.10
Time Consuming	2.00	1.61	1.87	1.87
Complicated	1.89	2.62	1.61	1.91
EQIP	2.05	2.70	1.60	1.92
Manure Handling	1.25	1.23	1.27	1.25
Solid				
Solid and Liquid	4.67	5.03	4.67	4.70
Total Animal Units	3.81	3.81	3.62	3.62
Species Dummy	1.63	1.68	1.65	1.64
Dairy				
Beef Cow	2.18	2.65	2.64	2.58
Beef Cattle	1.89	2.67	2.48	2.47
Poultry	1.97	2.31	2.16	2.21
Turkey	1.57	2.01	1.92	1.86
Other	1.68	2.19	2.11	2.22

CHAPTER 7: ENVIRONMENT-ORIENTED VERSUS PROFIT-ORIENTED PRACTICES

7.1. Introduction

Studies that analyzed adoption of new technologies or practices have examined either primarily environment-oriented or primarily profit-oriented technologies (some technologies impact only environmental quality or profitability, while many impact both). However, the previous studies that analyzed adoption of environment-oriented technologies used adoption theories that are primarily developed for profit-oriented technologies. The hypotheses formed based on these theories may not be appropriate for environment-oriented technologies. A utility maximization framework rather than a profit maximization framework may be more appropriate for environment-oriented technologies and environmental attitudes may be important. As detailed in the literature review chapter, previous studies, which are summarized in table 30, show inconsistent findings regarding the impact of some variables such as farm size and age on adoption of environment-oriented and profit-oriented technologies. For example, farm size has a positive impact on adoption of profit-oriented technologies, while it can have positive, negative or no-impact on adoption of environment-oriented technologies.

The contribution of the current analysis is that by simultaneously incorporating both environment-oriented and profit-oriented technologies into the econometric analysis, it may provide insight about the similarities and differences regarding signs and relative magnitudes of factors affecting adoption of these technologies. This knowledge will help policy makers know whether different policies are needed to promote environment-oriented technologies.

Table 30: Impact of Selected Variables on Adoption of Technology (from reviewed articles)

Variable	Profit-Oriented Technology			Environment-Oriented Technology		
	Positive	Negative	No Impact	Positive	Negative	No Impact
Profitability	√		√	√		√
Farm Size	√			√	√	√
Credit Constraint		√				
Soil Quality	√			√		
Risk Aversion		√			√	
Education	√			√		√
Information (Extension)	√			√		√
Age		√	√	√	√	√
Environmental Attitude				√		√

7.2. Model

For the empirical model, the adoption decision that farmers make for the practices can be represented with a random utility framework for environment-oriented practices and a stochastic profit framework for profit-oriented practices (Green, 2003).

For a profit-oriented practice, profit gained from adoption of a practice is compared to profit from not adopting the practice. If the profit from adopting the practice is bigger than the profit from not adopting the practice, then the farmer adopts the practice. If the profit from adopting the practice is less than or equal to the profit from not adopting the practice, then the farmer does not adopt the practice.

The profit function $\Pi(.)$ is assumed to be a function of age (AGE), education (EDUC), off-farm income (OFI), farm sales (FS), farmer's plan to continue farming (CF) and expanding livestock numbers (EL), perceptions about the profitability of the practice (PPP), influence of financial and government organizations on farmer's decisions (IGO), manure handling systems (MHS), and livestock specie (LS). It is also assumed that the profit has a random factor ε, which is assumed to have a normal distribution. The profit function $\Pi(.)$ then can be represented as;

$$\pi(AGE, EDUC, OFI, FS, CF, EL, PPP, IGO, MHS, LS, \varepsilon)$$

If π_a represents the level of utility from adopting a practice and π_b represents the level of utility from not adopting the practice, then the decision whether to adopt a practice or not can be represented as;

$y_i = 1$ (farmer adopts the practice) if $\pi_a > \pi_b$

$y_i = 0$ (farmer does not adopt the practice) if $\pi_a \leq \pi_b$

For an environment-oriented practice, the utility gained from adoption of a practice is compared to utility from not adopting the practice. If the utility from adopting the practice is greater than the utility from not adopting the practice, then the farmer adopts the practice. If the utility from adopting the practice is less than or equal to the utility from not adopting the practice, then the farmer does not adopt the practice.

The utility function $U(.)$ is assumed to be a function of age (AGE), education (EDUC), off-farm income (OFI), farm sales (FS), perceptions about the environment (EP), the farmer's plans to continue farming (CF) and expand livestock numbers (EL), perceptions about the impact of the practice on the environment (PPE), perceptions about the profitability of the practice (PPP), influence of financial and government organizations on the farmer's decisions (IGO), manure handling systems (MHS), and livestock specie (LS). It is also assumed that the utility has a random factor ε, which is assumed to have a normal distribution.

The perceptions about the profitability of the practices included into the utility function as profitability of practices will impact the farmers' ability to purchase consumers goods, hence causes the utility to increase. The fact that farmers are the protectors of the environment is reflected by having perceptions about the environment and impact of the practices on the environment in the utility function. It is expected that farmers get utility from conserving the environment.

The utility function $U(.)$ can be represented as;

$$\mathrm{U}\left(AGE, EDUC, OFI, FS, EP, CF, EL, PPE, PPP, IGO, MHS, LS, \varepsilon\right)$$

If U_a represents the level of utility from adopting a practice and U_b represents the level of utility from not adopting the practice, then the decision whether to adopt a practice or not can be represented as;

$y_i = 1$ (farmer adopts the practice) if $U_a > U_b$

$y_i = 0$ (farmer does not adopt the practice) if $U_a \leq U_b$

Hypotheses that are going to be tested are based on the perceptions of farmers about the environment and perceptions about the practice. It is expected that perceptions about the environment will not impact adoption of a profit-oriented practice and perceptions about profitability of the practice will not impact adoption of an environment-oriented practice. Specific hypotheses that are going to be tested are;

- If a farmer disagrees with the statement "I am concerned about the water quality of streams and lakes in my county.", then the farmer is less likely to adopt an environment-oriented practice. But adoption of a profit-oriented technology is not impacted by this variable.

- If a farmer disagrees with the statement "Properly managing manure improves water quality.", then the farmer is less likely to adopt an environment-oriented practice. But adoption of a profit-oriented technology is not impacted by this variable.
- If a farmer disagrees with the statement "Agricultural regulations regarding water quality will become stricter in the next five years.", then the farmer is less likely to adopt an environment-oriented practice. But adoption of a profit-oriented technology is not impacted by this variable.
- If a farmer disagrees with the statement "This practice improves water quality.", then the farmer is less likely to adopt an environment-oriented practice. But adoption of a profit-oriented technology is not impacted by this variable.
- If a farmer disagrees with the statement "This is a profitable practice, it improves my bottom line.", then the farmer is less likely to adopt a profit-oriented practice. Adoption of an environment-oriented technology is less impacted by this variable.

7.3. Results and Discussion

For both environment-oriented and profit-oriented practices, the factors that impact adoption can be analyzed using univariate probit / logit models. In the current study, the univariate probit model that is analyzed in chapter 4 of the dissertation is used for each practice / technology. Hence, four different regressions are obtained. Some of the significant variables will be discussed in this section. The data set used in the regressions is the same data set that was used for chapter 6 of the dissertation, except in the case of Roundup Ready soybeans, the farmers that do not have soybean production are also removed from the data set, as adoption of Roundup Ready soybeans is irrelevant for them.

Some of the agricultural practices or technologies can be both environment and profit oriented, while others can be only environment or profit oriented. In the current study, as discussed in chapter 2 of the dissertation, Roundup Ready soybeans is used as profit-oriented technology, manure testing and calibrating manure spreaders both profit and environment-oriented, and maintaining a setback as an environment-oriented practice. Results are presented in table 31.

Multicollinearity for all the regressions is checked using the VIF. The results are represented in table 33. The only variables that had VIF that is greater than 10 were age and age squared. Since age square is derived directly from age, this result is natural. For the rest of the variables, all the VIF values were less than 10. This shows that multicollinearity did not exist in any of the regressions.

Fit statistics of the regression are presented in table 31. The Wald test statistics for all the regressions have p values of 0.00. This shows that all the regressions are statistically significant. However, when the presudo R-square values are compared, it is seen that the fit for the Roundup Ready soybeans is high but the fit for maintaining setbacks is low, which is 68% and 18% respectively. This shows that future research that includes additional variables in the regression is needed to explain the variation in adoption of maintaining setbacks.

7.3.1. Age

Age is found to have a negative impact on Roundup Ready soybeans and maintaining setbacks. The squared term is significant only for Roundup Ready soybeans, which shows that the impact of age diminishes as age increases. Younger farmers might be more innovative than older farmers and more environmentally concerned or aware.

7.3.2. Education

In the literature, education is found to positively impact adoption of both profit-oriented and environment-oriented practices. The results of the current study show that farmers with less than a high school education are less likely to adopt Roundup Ready soybeans and maintaining setbacks than farmers with a high school degree. Farmers with a bachelor degree are more likely to adopt manure testing than farmers with a high school degree. It is also found that farmers with a graduate degree are less likely to adopt Roundup Ready soybeans than farmers with high school education.[7] Overall, there was not a linear relationship between education and adoption of practices. This might show some evidence that the impact of different levels of education diminishes as the level of education increases.

7.3.3. Off-Farm income

Off-farm income has no significant impact on environment-oriented practices. It could be that farmers, whose primary occupation is farming, are driven more by profits since that is the only way they feed their families. For the profit oriented practice, Roundup Ready soybeans, farmers with no off-farm income and farmers with off-farm income of \$0-\$9,999 are more likely to adopt than farmers with off-farm income of

[7] There were only four farmers with a graduate degree and only one of them adopted Roundup Ready soybeans.

$10,000-$24,999. Also, farmers with off-farm income of $25,000-$49,999 are found to be more likely to adopt Roundup Ready soybeans than farmers with off-farm income of $10,000-$24,999. There is evidence that off-farm income does not impact adoption environment-oriented practices, where as off-farm income impacts adoption of a profit-oriented practice, but there is no linear relationship between off-farm income levels and the probability to adopt the practice.

7.3.4. Farm sales

Farm sales show similar impacts on adoption of profit-oriented and environment-oriented practices. Farmers with farm sales of $10,000-$99,999 are less likely to adopt Roundup Ready soybeans, calibrating manure spreaders, and maintaining setbacks than farmers with farm sales of $100,000-$249,999, which is the base category. It is also found that farmers with farm sales of $500,000 or more are more likely to adopt Roundup Ready soybeans, manure testing, calibrating manure spreaders, and maintaining setbacks than farmers with farm sales of $100,000-$249,999. The results are in line with the literature. However, since none of the four practices used in the regression require up front investment, the impact of farm sales can not be attributed to a credit constraint or economies of scale, which are typically suggested as explanations for the impact of farm sales. It could be that farmers with the largest farm sales can be both environmentally friendly and innovative, as they are more likely to adopt a profit orient practice.

7.3.5. Environmental perceptions

The impact of environmental perceptions on adoption of profit-oriented practices has not been tested in the literature. Some of the perceptions about the environment, although not directly linked to water quality, are also included in the regressions in addition to the perceptions linked directly to water quality. The results of the current study provide evidence that environmental perceptions might impact the adoption of profit-oriented practices.

For the perceptions about the environment not directly linked to water quality, if the farmer disagrees with the statement that the smell of manure bothers me or my family, the farmer is more likely to adopt Roundup Ready soybeans and manure testing than a farmer who agrees with the statement. The manure testing result is expected as testing manure requires being around it and those who dislike the smell will avoid manure if possible. The link between Roundup Ready soybeans and not being bothered by the smell of manure does not have an obvious explanation and requires further research. For smell of manure bothers my neighbors, farmers who disagree with the statement are less likely to adopt Roundup Ready soybeans and more likely to adopt manure testing and calibrating manure spreaders than farmers that agree with the statement. For Roundup Ready soybeans, farmers that agree with the statement may be more likely to specialize in crop production since they might know that their neighbors are bothered when manure is applied but this question needs additional research.

It is also found that, if a farmer is not unsure about how crops respond to manure as compared to commercial fertilizer, then the farmer is more likely to adopt Roundup Ready soybeans and calibrating manure spreaders. It can be that farmers that apply manure and calibrate their manure spreaders know how their crops respond to manure. Also, if a farmer disagrees that transportation costs and time affect which of the farmer's fields receive manure, the farmer is less likely to adopt Roundup Ready soybeans. The farmers that have liquid manure handling system, which we expect not to be primarily crop farmers, did not agree with the statement that transportation costs and time affect which of the farmer's fields receive manure. This shows that farmers that disagreed with the statement are more likely to be livestock farmers that have smaller cropped acreage.

Perceptions that are directly linked to water quality were hypothesized to impact adoption of only environment-oriented practices. If a farmer disagrees with the statement that I am concerned about the water quality of streams and lakes in my county, then the farmer is more likely to adopt maintaining setbacks. This result is not in line with the hypotheses. For the other practices, there is no significant difference between farmers who agree with the statement and disagree. Finding that adoption of Roundup Ready soybeans is not impacted from agreeing or disagreeing to this statement is in line with the hypothesis. Farmers who disagree that properly managing manure improves water quality are more likely to adopt calibrating manure spreaders than the farmers who do not agree with the statement. It could be that farmers calibrate the manure spreader for profit or yield reasons. For the other practices, there is no significant difference between farmers who agree with the statement and who disagree. If the farmers disagree that agricultural regulations regarding water quality will become stricter, then they are less likely to adopt calibrating manure spreaders than farmers who agree with the statement. For other practices there is no statistically significant difference between farmers who agree and disagree with the statement.

The results of the current study provide evidence that environmental perceptions can also impact the adoption of a profit-oriented practice, but this impact can be the opposite as compared to an environment-oriented practice. This can be seen by the opposite sign for "smell of manure bothers my neighbors" for Roundup Ready soybeans as compared to manure testing and calibrating manure spreaders. This may be a spurious correlation and more research may be needed. The results show variability of the impact of environmental perceptions among environment-oriented and both environment and profit-oriented practices. For example, “properly managing manure improves water quality” is only significant for calibrating manure spreaders. However, in the next section, this question is examined for specific practices. However, overall, it is seen that perceptions about the environment are not impacting adoption of both environment and profit-oriented practices greatly. Factors other than perceptions about the environment can be more important determinants of the adoption of practices. Hence, even if farmers believe that they are or should be stewards of the environment, this does mean that they will definitely adopt environment-oriented practices.

7.3.6. Perceptions about the practices

Perceptions about profitability of the practices are expected to impact adoption of profit oriented practices as well as environmentally oriented ones. Perceptions about the impact on water quality of practices are expected to impact adoption of only environment-oriented practices.

For the perception about the profitability of the practices, farmers who disagree that the practice is profitable are less likely to adopt Roundup Ready soybeans, manure testing, calibrating manure spreaders, and maintaining setbacks than farmers who agree with the statement. This results shows that being profitable is an important factor that impacts adoption of practices with different characteristics and is in line with our models.

For the statement “this practice improves water quality”, farmers who disagree with the statement are less likely to adopt Roundup Ready soybeans than farmers who agree. For other practices, there is no statistically significant difference between farmers who disagree with the statement and who agree. The result for the Roundup Ready soybeans can provide evidence that the impact of a practice on the environment impacts the adoption of that practice, even if it is primarily profit-oriented.

Being time consuming is significant only for Roundup Ready soybeans. Farmers who disagree that Roundup Ready is time consuming are less likely to adopt than farmers who disagree to that. It can be that farmers who adopted Roundup Ready soybeans experienced that it is time consuming. For being complicated, there is a statistically significant difference between farmers who agreed and who disagreed only for manure testing and calibrating manure spreaders. Farmers that disagree manure testing and calibrating manure spreaders are complicated are more likely to adopt than farmers who agree. This result is in line with expectations.

Overall, it would be valuable to learn if the perceptions about practices are formed before the adoption decision or after adoption or both. This point requires further research, ideally using a panel dataset.

7.3.7. Influence of government organizations

For the impact of organizations on farmers' agricultural production decisions, the results indicate that banking institutions, contractors, university and NRCS differentially impact adoption of Roundup Ready soybeans. If banks, contractors and university have no influence on farmers' decisions, these farmers are more likely to adopt Roundup Ready soybeans. It might be that these farmers are self-confident or affected by other sources such as neighbors and the sales representatives for Roundup Ready soybeans. If NRCS does not have an influence on farmers' production decisions, then these farmers are less likely to adopt Roundup Ready soybeans. For manure testing, farmers that are not influenced by banking institutions are more likely to adopt than farmers who are influenced. This may indicate they are in good shape financially. However, farmers who are not influenced by contractors and NRCS are less likely to adopt than farmers who are influenced.

These results imply that these organizations might not impact adoption of all the practices. NRCS provides funding and technical support for environment-oriented practices. However, adoption of calibrating manure spreaders and maintaining setbacks are not impacted by NRCS. It is not surprising that banking institutions and contractors had no impact on adoption of calibrating manure spreaders and maintaining setbacks, since none of the practices require a large investment and there is little incentive for contractors to place importance on the environment because the growers are legally responsible for that. However, finding that university is not significant for environment-oriented practices is surprising and requires further investigation. It could be that farmers may not have been thinking about the Extension Service as part of their university when answering the question.

7.3.8. Manure handling systems

For the type of manure handling system, it is seen that farmers that have only solid manure handling systems are less likely to adopt Roundup Ready soybeans, manure testing and calibrating manure spreaders, and more likely to adopt maintaining setbacks than farms with only liquid manure handling systems. This is also the same for farmers that have both solid and liquid manure handling systems. As mentioned in Chapter 6 of the dissertation, farmers with only liquid manure handling systems are expected to be swine operations, which have less land than beef cattle or beef cow operations that are more likely to be primarily crop farmers. Hence, farmers with only solid or both solid and liquid manure handling systems are more likely to adopt Roundup Ready soybeans. Since the solid form of manure would have less variability in terms of nutrient content since dilution rates and volatilization aren't an issue, farmers with only solid or both solid and liquid manure handling systems might be less likely to test the manure for nutrient content. It may also be more difficult to obtain a representative sample from a manure pile. Also, since the farmers with only liquid manure handling systems would be handling more manure and using irrigation systems, they might be more likely to calibrate their spreaders than farmers with other types of manure handling systems. Overall, these results provides strong evidence the way manure handled in the farm, and the farming system, impacts adoption of both profit-oriented and environment-oriented practices.

7.3.9. Species

For Roundup Ready soybeans, dairy, poultry and turkey operations are less likely to adopt, and beef cattle operations are more likely to adopt, than swine operations. It is found that dairy, poultry and turkey operations have less land that is cropped with soybeans than swine operations, which show that they specialize more in livestock. The opposite is true for the beef cattle operations. For manure testing, both dairy and turkey operations are more like to adopt than swine operations. For calibrating manure spreaders, beef cattle, poultry and turkey operations are more likely to adopt than swine operations. This is somewhat surprising since manure testing and calibration are both needed to apply appropriate rates of manure. For maintaining setbacks, dairy, beef cattle, poultry and operations with other species are less likely to adopt than swine operations. Since swine operations handle liquid manure, which might be applied to field more frequently, they might be more careful about maintaining a setback or they might be more sensitive to neighbors' complaints.

The adoption rate for Roundup Ready soybeans, a straightforward and profit-oriented practice, is 53%. The nature of the practice may explain the higher number of statistically significant number of variables. Adoption rates for manure testing and calibrating manure spreaders are 29% and 24%, respectively and the motivations for and implications of adopting these practices are not as clear. It could be that other variables, not included in our analyses, are important.

7.3.10. Marginal effects

Marginal effects of each variable on the probability of adopting each practice are presented in table 32. The method used in calculating the marginal effects is the same as the method used in Chapter 6. Some of the marginal effects for the variables that were found significant in the regression will be discussed below.

For the profit oriented practice, having an education level that is less than high school, having a graduate degree, disagreeing that smell of manure bothers farmer's neighbor, and being a poultry or turkey operation are the variables that impact the adoption of Roundup Ready soybeans the most.

For manure testing, disagreeing that it is complicated, having solid manure handling systems and being a turkey operation are the most effective variables that impact adoption. For calibrating manure spreaders, disagreeing managing manure improves water quality, disagreeing it is complicated, having a solid manure handling system, and being either a poultry or turkey operation are the most effective variables for adoption. For maintaining a setback, having less than a high school education, disagreeing that it improves water quality, having a solid manure handling system, and being either a dairy or poultry operation are the most effective variables that impact adoption.

Overall, perceptions about the practices, manure handling systems and the species are the most common factors that impacting highly adoption of environment-oriented and profit-oriented practices. This shows that the focus of the policies should be providing more information about the benefits of the practices and finding the most appropriate practices for the different farming systems.

7.4. Conclusion

The purpose of this study is to determine if there are similarities and dissimilarities between adoption of environment-oriented and profit oriented practices. When studies first started to analyze adoption of new technologies or practices by farmers, the technologies or the practices that were subject to analysis were mostly profit-oriented or increasing the yield for farmers. However, currently there are technologies or practices being promoted that are environment-oriented or that are expected to increase environmental quality and which have primarily off-farm benefits.

Government organizations that build policies toward increasing the adoption rate of environment-oriented practices can get information from previous studies or use the experiences from previous policies. However, most of the previous information is based on adoption of profit-oriented practices. Hence, use of this information when building policies towards adoption of environment-oriented practices may not be appropriate. To address this issue, the similarities and dissimilarities between adoption of environment-oriented and profit-oriented practices / technologies are examined in the current study, which could then be used by policy makers for designing more effective policies that promote environmental quality.

In the current study, besides looking at the impact of certain variables on the adoption of environment and profit-oriented practices, it was also hypothesized that the main difference between adoption of these practices would come from perceptions of farmers about environmental quality and the profitability of these practices. Hence, it was hypothesized that adoption of the environment-oriented practices would be impacted from farmers' general perceptions about the water quality and perceptions about the impact of the practices on water quality, as well as profitability of the practices. Adoption of profit-oriented practices was hypothesized to be impacted from profitability but not the perceptions of farmers about the water quality or the impact of the practice on the water quality.

The results of the current study showed that perceptions about the water quality or the environment are not important in adoption of environment-oriented practices, which contradicted the hypotheses. It was seen that the profitability of the practices, even for the environment-oriented practices, is a very important factor that impacts adoption of all type of practices. These results show that farmers would not adopt a practice if they believe it is not profitable, even though the farmers are concerned about the environmental quality. This shows the need for cost share or incentive programs to promote environmental programs as farmers are not self motivated to adopt environment-oriented practices.

Among the other variables that were analyzed, farm sales and education were found to impact both type of practices positively. However, off-farm income and government organizations impacted only adoption of profit-oriented practices. Type of manure handling systems and livestock species also impacted adoption of both types of practices, although the impact was in opposite direction for manure handling systems. It was also found that these two factors were among most important factors that impact adoption of environment-oriented practices.

Overall, there are both similarities and dissimilarities between adoption of environment and profit-oriented practices / technologies. This may be partly due to the fact that all the practices examined have effects on both the environment and profitability.

The theory for adoption of profitable practices is well-established but less so for environmental practices. This is also reflected by the differences in the R-square values of the regressions for Roundup Ready soybeans and maintaining a setback, which are 68% and 18% respectively. This requires policy makers to search for additional information about the farmers and farming systems when designing policies towards promoting environmental quality.

Table 31: Results for Univariate Probit Regressions

Variable	Roundup Ready		Manure Testing		Calibrating Manure Spr.		Maintaining Setbacks	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Age	-0.28	0.05	-0.09	0.12	0.03	0.65	-0.07	0.09
Age^2	0.00	0.04	0.00	0.13	0.00	0.95	0.00	0.11
Iowa	1.33	0.01	0.35	0.13	0.29	0.17	-0.27	0.07
Education								
Less than High School	-2.41	0.01	-0.14	0.68	-0.16	0.64	-0.71	0.00
Some College or Vocational School	0.23	0.65	0.05	0.79	-0.26	0.23	0.05	0.77
Bachelor Degree	0.15	0.79	0.51	0.05	-0.13	0.65	0.08	0.67
Graduate Degree	-4.10	0.00	-0.07	0.92			-0.46	0.37
Off-farm Income								
None	3.40	0.00	-0.19	0.48	0.17	0.56	0.04	0.85
$0 - $9,999	5.15	0.00	0.16	0.59	-0.15	0.63	0.28	0.20
$25,000 - $49,999	1.18	0.05	0.35	0.20	0.11	0.71	0.09	0.66
$50,000 - $99,999	-0.21	0.79	0.33	0.29	0.33	0.34	0.32	0.19
$100,000 +	0.04	0.97	-0.40	0.46	-0.60	0.52	0.04	0.93
Farm Sales								
$10,000 - $99,999	-2.28	0.00	-0.35	0.15	-0.47	0.04	-0.34	0.04
$250,000 - $499,999	0.91	0.11	-0.15	0.54	-0.09	0.71	0.24	0.17
$500,000 +	1.84	0.02	0.62	0.03	0.83	0.00	0.40	0.08
Smell of Manure Bothers Me or My Family								
Disagree	1.07	0.09	0.73	0.01	-0.40	0.21	-0.18	0.39
Neutral	2.19	0.00	0.28	0.30	-0.12	0.68	0.01	0.98
Smell of Manure Bothers My Neighbors								
Disagree	-3.24	0.00	0.49	0.08	0.71	0.02	0.09	0.63
Neutral	-0.56	0.36	0.26	0.32	0.41	0.16	0.11	0.56
Not Sure How Crops Respond to Manure								
Disagree	1.07	0.10	-0.41	0.15	0.91	0.00	0.26	0.19
Neutral	0.52	0.39	-0.09	0.79	-0.01	0.99	0.04	0.86
Concerned about the Water Quality								
Disagree	-0.11	0.89	-0.41	0.32	0.12	0.76	0.47	0.10
Neutral	0.13	0.82	-0.30	0.39	0.90	0.00	-0.14	0.52
Managing Manure Improves Water Quality								
Disagree	-0.68	0.45	-0.66	0.26	1.01	0.03	-0.37	0.29
Neutral	-0.42	0.43	0.13	0.68	-0.59	0.11	0.16	0.48
Regulations will be Stricter								
Disagree	-0.22	0.82	0.48	0.40	-1.62	0.01	0.14	0.71
Neutral	1.39	0.01	-0.01	0.96	0.26	0.29	-0.07	0.66
Transportation Costs and Time Affect Which of My Fields Receive Manure								
Disagree	-1.85	0.00	0.24	0.24	0.26	0.22	0.02	0.87
Neutral	-0.22	0.67	-0.27	0.28	0.00	0.99	-0.22	0.21

Table 31: Results for Univariate Probit Regressions (Continued)

Variable	Roundup Ready		Manure Testing		Calibrating Manure Spr.		Maintaining Setbacks	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Continue Farming								
Yes	-1.26	0.05	-0.08	0.81	0.06	0.86	-0.02	0.93
Not Sure	-7.12	0.00	-1.04	0.16	0.08	0.88	-0.40	0.36
Expand Livestock Numbers								
Yes	1.19	0.01	-0.04	0.84	0.19	0.38	-0.20	0.21
Not Sure	-1.10	0.02	-0.01	0.95	0.09	0.69	-0.32	0.04
Profitable								
Disagree	-1.42	0.09	-1.86	0.00	-1.34	0.00	-0.51	0.00
Neutral	-3.69	0.00	-1.19	0.00	-1.52	0.00	-0.49	0.00
Improves Water Quality								
Disagree	-2.94	0.00	0.16	0.65	-0.47	0.25	-0.32	0.38
Neutral	-0.81	0.09	-0.26	0.23	-0.25	0.32	-0.86	0.00
Time Consuming								
Disagree	-3.49	0.00	0.05	0.87	-0.01	0.98	0.17	0.46
Neutral	-5.82	0.00	-0.01	0.98	-0.02	0.95	0.28	0.24
Complicated								
Disagree	1.25	0.11	1.50	0.00	1.17	0.00	0.05	0.83
Neutral	3.25	0.00	0.86	0.01	0.11	0.67	-0.15	0.57
Bank								
No Influence	1.04	0.06	0.60	0.03	0.33	0.22	0.29	0.16
Some Influence	1.29	0.02	0.58	0.03	-0.28	0.35	0.18	0.39
Contractor								
No Influence	1.51	0.08	-0.73	0.02	0.30	0.40	-0.02	0.95
Some Influence	2.36	0.01	-0.52	0.12	-0.04	0.91	0.32	0.25
University								
No Influence	3.74	0.00	0.32	0.31	-0.13	0.65	0.12	0.59
Some Influence	2.32	0.00	0.12	0.65	0.10	0.73	0.16	0.43
NRCS								
No Influence	-2.44	0.00	-0.83	0.00	-0.25	0.38	-0.23	0.25
Some Influence	-2.32	0.00	-0.53	0.04	-0.08	0.77	-0.20	0.32
Manure Handling								
Solid	-2.78	0.00	-1.28	0.00	-1.91	0.00	0.67	0.01
Solid and Liquid	-2.01	0.01	-0.86	0.01	-1.19	0.00	0.41	0.09
Total Animal Units	0.00	0.00	0.00	0.02	0.00	0.81	0.00	0.60
Species Dummy								
Dairy	-2.28	0.01	0.43	0.13	0.31	0.30	-0.61	0.00
Beef Cow	1.54	0.02	-0.27	0.40	0.92	0.01	-0.46	0.04
Beef Cattle	0.30	0.67	-0.35	0.44	-0.28	0.46	-0.33	0.18
Poultry	-3.38	0.00	0.54	0.23	1.76	0.00	-0.90	0.01
Turkey	-4.65	0.00	0.86	0.05	1.64	0.00	-0.47	0.15
Other			-0.40	0.52	0.76	0.19	-0.91	0.04
Constant	10.81	0.01	1.32	0.39	-2.66	0.19	2.24	0.07
Wald Chi-Square	155	0.00	205	0.00	203	0.00	129	0.00
Pseudo R-Square	68%		49%		43%		18%	

Table 32: Marginal Effects (dy/dx) for Univariate Probit Regressions

Variable	Roundup Ready	Manure Testing	Calibrating Manure Spr.	Maintaining Setbacks
	dy/dx	dy/dx	dy/dx	dy/dx
Age	0.000	-0.011	0.003	-0.028
Age^2	0.000	0.000	0.000	0.000
Iowa	0.000	0.043	0.031	-0.102
Education				
Less than High School	-0.013	-0.016	-0.016	-0.278
Some College or Vocational School	0.000	0.007	-0.026	0.017
Bachelor Degree	0.000	0.084	-0.013	0.030
Graduate Degree	-0.310	-0.009		-0.180
Off-farm Income				
None	0.000	-0.023	0.019	0.014
$0 - $9,999	0.000	0.022	-0.016	0.103
$25,000 - $49,999	0.000	0.051	0.012	0.033
$50,000 - $99,999	0.000	0.051	0.045	0.117
$100,000 +	0.000	-0.038	-0.041	0.016
Farm Sales				
$10,000 - $99,999	-0.004	-0.040	-0.044	-0.131
$250,000 - $499,999	0.000	-0.018	-0.010	0.087
$500,000 +	0.000	0.109	0.143	0.143
Smell of Manure Bothers Me or My Family				
Disagree	0.000	0.102	-0.043	-0.069
Neutral	0.000	0.038	-0.013	0.002
Smell of Manure Bothers My Neighbors				
Disagree	-0.014	0.071	0.095	0.036
Neutral	0.000	0.035	0.048	0.040
Not Sure How Crops Respond to Manure				
Disagree	0.000	-0.058	0.086	0.099
Neutral	0.000	-0.012	-0.001	0.015
Concerned about the Water Quality				
Disagree	0.000	-0.040	0.014	0.164
Neutral	0.000	-0.032	0.168	-0.056
Managing Manure Improves Water Quality				
Disagree	0.000	-0.054	0.208	-0.144
Neutral	0.000	0.017	-0.045	0.059
Regulations will be Stricter				
Disagree	0.000	0.084	-0.063	0.050
Neutral	0.000	-0.002	0.033	-0.028
Transportation Costs and Time Affect Which of My Fields Receive Manure				
Disagree	0.000	0.031	0.029	0.009
Neutral	0.000	-0.031	0.000	-0.083

Table 32: Marginal Effects (dy/dx) for Univariate Probit Regressions (Continued)

Variable	Roundup Ready	Manure Testing	Calibrating Manure Spr.	Maintaining Setbacks
	dy/dx	dy/dx	dy/dx	dy/dx
Continue Farming				
Yes	0.000	-0.011	0.006	-0.008
Not Sure	-0.991	-0.064	0.009	-0.157
Expand Livestock Numbers				
Yes	0.000	-0.005	0.022	-0.076
Not Sure	0.000	-0.002	0.010	-0.123
Profitable				
Disagree	-0.001	-0.120	-0.079	-0.188
Neutral	-0.086	-0.131	-0.157	-0.126
Improves Water Quality				
Disagree	-0.032	0.023	-0.039	-0.333
Neutral	0.000	-0.031	-0.026	0.065
Time Consuming				
Disagree	0.000	0.006	-0.001	0.105
Neutral	-0.742	-0.001	-0.002	0.021
Complicated				
Disagree	0.000	0.293	0.225	-0.057
Neutral	0.000	0.120	0.012	-0.188
Bank				
No Influence	0.000	0.074	0.036	0.111
Some Influence	0.000	0.088	-0.028	0.069
Contractor				
No Influence	0.000	-0.123	0.029	-0.006
Some Influence	0.000	-0.051	-0.005	0.116
University				
No Influence	0.002	0.041	-0.015	0.044
Some Influence	0.000	0.016	0.011	0.061
NRCS				
No Influence	-0.001	-0.104	-0.027	-0.089
Some Influence	-0.001	-0.060	-0.009	-0.076
Manure Handling				
Solid	0.000	-0.218	-0.338	0.258
Solid and Liquid	-0.001	-0.084	-0.094	0.149
Total Animal Units	0.000	0.000	0.000	0.000
Species Dummy				
Dairy	-0.003	0.065	0.039	-0.238
Beef Cow	0.000	-0.031	0.149	-0.179
Beef Cattle	0.000	-0.037	-0.026	-0.130
Poultry	-0.102	0.096	0.479	-0.346
Turkey	-0.475	0.178	0.418	-0.186
Other		-0.038	0.143	-0.348

Table 33: Multicollinearity Analyses for Univariate Probit Regressions

Variable	Roundup Ready	Manure Testing	Calibrating Manure Spr.	Maintaining Setbacks
	VIF	VIF	VIF	VIF
Age	90.43	60.91	60.34	61.18
Age^2	90.99	60.63	60.07	60.72
Iowa	1.71	1.63	1.62	1.60
Education				
Less than High School	1.71	1.56	1.55	1.57
Some College or Vocational School	1.41	1.33	1.34	1.32
Bachelor Degree	1.41	1.37	1.37	1.37
Graduate Degree	1.19	1.18	1.19	1.19
Off-farm Income				
None	2.60	2.35	2.37	2.37
$0 - $9,999	1.99	1.81	1.79	1.78
$25,000 - $49,999	2.55	2.29	2.22	2.22
$50,000 - $99,999	1.87	1.71	1.66	1.69
$100,000 +	1.33	1.32	1.29	1.29
Farm Sales				
$10,000 - $99,999	1.65	1.43	1.46	1.45
$250,000 - $499,999	1.49	1.41	1.43	1.40
$500,000 +	1.84	1.57	1.56	1.57
Smell of Manure Bothers Me or My Family				
Disagree	3.13	3.23	3.21	3.19
Neutral	2.46	2.58	2.54	2.58
Smell of Manure Bothers My Neighbors				
Disagree	2.62	2.57	2.56	2.55
Neutral	2.09	2.12	2.13	2.15
Not Sure How Crops Respond to Manure				
Disagree	3.10	2.54	2.51	2.54
Neutral	2.8	2.33	2.34	2.37
Concerned about the Water Quality				
Disagree	1.81	1.65	1.65	1.65
Neutral	1.33	1.22	1.24	1.28
Managing Manure Improves Water Quality				
Disagree	2.08	2.17	2.15	2.15
Neutral	1.28	1.22	1.20	1.23
Regulations will be Stricter				
Disagree	2.02	1.77	1.72	1.75
Neutral	1.3	1.24	1.26	1.24
Transportation Costs and Time Affect Which of My Fields Receive Manure				
Disagree	1.64	1.59	1.57	1.57
Neutral	1.52	1.48	1.45	1.46

Table 33: Multicollinearity Analyses for Univariate Probit Regressions (Continued)

Variable	Roundup Ready	Manure Testing	Calibrating Manure Spr.	Maintaining Setbacks
	VIF	VIF	VIF	VIF
Continue Farming				
Yes	1.65	1.54	1.54	1.57
Not Sure	1.49	1.44	1.43	1.45
Expand Livestock Numbers				
Yes	1.68	1.53	1.55	1.53
Not Sure	1.41	1.32	1.34	1.32
Profitable				
Disagree	1.73	1.85	1.93	1.41
Neutral	1.43	1.89	2.16	1.48
Improves Water Quality				
Disagree	1.68	1.72	1.84	1.20
Neutral	1.39	1.75	2.06	1.51
Time Consuming				
Disagree	5.24	2.36	2.62	4.11
Neutral	3.91	2.16	2.69	3.58
Complicated				
Disagree	4.98	2.82	2.67	4.78
Neutral	3.80	2.50	2.60	3.89
Bank				
No Influence	3.39	3.03	2.97	2.98
Some Influence	2.99	2.76	2.72	2.74
Contractor				
No Influence	4.97	3.66	3.71	3.70
Some Influence	4.49	3.33	3.34	3.33
University				
No Influence	3.96	3.45	3.40	3.38
Some Influence	3.39	2.80	2.77	2.76
NRCS				
No Influence	3.00	2.84	2.88	2.85
Some Influence	2.79	2.41	2.42	2.42
Manure Handling				
Solid	4.52	4.41	4.17	4.23
Solid and Liquid	3.46	3.43	3.39	3.39
Total Animal Units	1.79	1.55	1.50	1.51
Species Dummy				
Dairy	2.40	2.54	2.49	2.47
Beef Cow	3.07	2.60	2.63	2.68
Beef Cattle	2.36	2.16	2.16	2.14
Poultry	1.60	1.79	1.77	1.79
Turkey	1.71	2.25	2.22	2.31
Other	1.55	1.24	1.24	1.27

CHAPTER 8: CONCLUSIONS

Livestock production has byproducts such as nitrogen and phosphorous and without proper management, these byproducts can degrade water sources (Aillery *et al*., 2005). To minimize the pollution from animal feeding operations, the U.S. Department of Agriculture and the Environmental Protection Agency promote the adoption of a comprehensive nutrient management plan. However, for animal feeding operations that are not classified as concentrated animal feeding operations, adoption of a comprehensive nutrient management plan is voluntary. Therefore, understanding the factors that affect voluntary adoption of practices / technologies that are part of a comprehensive nutrient management plan is important in the design of successful policies and programs to improve water quality.

Studies that analyzed adoption of practices / technologies looked at many factors that are related to characteristics of the farmer, farm and practices. Many studies included variables such as profitability, farm size and human capital into their analyses. However, the variables that were incorporated into the analyses of the previous studies could not explain adoption or non-adoption of some of the practices that were analyzed. This led researchers to search for new variables to add to their analyses.

One of the important factors that has changed recently is the off-farm income level of farmers. Hence, some recent studies incorporated the off-farm income of farmers into their analyses. However, most of the studies included only a dummy variable that indicated whether the farmer had off-farm income or not. These studies found divergent results regarding the impact of off-farm income on adoption of new practices /

technologies. Some studies found that having off-farm increases the probability of adopting a practice /technology, while others found the opposite. Also, the previous studies did not provide a framework that explains why having off-farm income impacts adoption of practices / technologies. The conceptual framework is needed as the relationship between off-farm income and adoption of practices could be only a correlation and not a structural relationship that policy makers could use to promote adoption of practices. Hence, a study was needed to explain the contradictory results of the previous studies and also to explain why having off-farm income impacts adoption of practices / technologies by providing a conceptual framework.

One of the objectives of this study was thus to develop a conceptual framework that would provide an explanation of why off-farm income affects adoption of agricultural practices / technologies. The conceptual framework is provided through an economic model that is based on static optimization, which represents a farmer's decision as to whether or not to adopt a practice / technology. It was hypothesized that if a farmer has off-farm income then the farmer has more financial sources to adopt a practice / technology that is capital intensive. Hence, a farmer with off-farm income is more likely to adopt a capital intensive technology. On the other hand, if a farmer has off-farm income, then the farmer has less time available to adopt a practice / technology that is time / labor intensive. Hence, a farmer with off-farm income less likely to adopt a practice / technology that is time / labor intensive.

For the empirical analyses, in contrast to having off-farm income as a dummy variable as in previous studies, the current study distinguished between off-farm work of the farm operator and the spouse, and also seasonal off-farm work and year-round off-farm work are separately included into the analyses. To account for the fact that farmers with high levels of off-farm income may not have farming as their the primary occupation, different levels of off-farm income were also incorporated into the empirical analyses. A multivariate probit model that accounts for the correlation among adoption of multiple practices is used for the empirical analyses, which is also a fairly new model for adoption studies. Also, imputation was done for missing data, which is again a fairly new technique in the context of adoption studies. Therefore this research contributes to the theoretical, empirical and methodological literature on technology adoption.

The empirical results of the current study provided evidence that when the farmer or the spouse have off-farm work, then the farmer is more likely to adopt a capital intensive technology. However, the results only partially supported the hypothesis for a time / labor intensive technology. Further studies with other, more labor-intensive, practices would be needed to confirm the hypothesis, and examine other potential explanations for the discrepancies in the literature on off-farm income. There is also need for future research incorporating the education level for the spouse and also the number of children at different age levels to get a complete picture of the farm family in the analyses. Finally, further research is needed to show the impact of off-farm income on adoption of practices that are neither capital nor time intensive.

Other finding of the current study is about the education level of the farmers. The general wisdom is that as the education level of farmers increases, they become more likely to adopt agricultural practices / technologies as farmers with higher education have higher human capital. However, the results of the current study show that there is no linear relationship between education level and probability of adopting a practice. It is found that farmers with high school education are more likely to adopt practices then farmers with education level of less than high school. However, farmers with education levels of higher than high school are not more likely to adopt practices than farmers with high school degree. It could be that in high school farmers get the most important knowledge and skills that enable them to find out about, evaluate and adopt practices. Also, education can be more important for new technologies whereas most of the technologies examined in this study were well-established.

Another important finding of the current study is related to the perceptions of the farmers about the environment. The general wisdom is that farmers with positive environmental attitudes will be more likely to adopt practices that conserve the environment. However, the current study provided evidence that positive perceptions about the environment are not enough farmers to adopt a practice. Farmers are more concerned about the attributes of the practices, such as profitability and complexity. Hence, it is very important for extension programs that farmers have full information about the benefits of the practices.

The results of the current study also showed that the type of manure handling system or the farming system is also a very important factor that impacts adoption of practices. Hence, besides the social or economic factors, policy makers should also examine the farming systems of the target farmers when policies towards improving the environmental quality are developed.

Analyzing the impact of off-farm income on the adoption of practices / technologies was one of the two major parts of the dissertation. The other major objective of dissertation was to identify the similarities and dissimilarities between adoption of primarily environment-oriented and profit-oriented practices.

When policies towards improving environmental quality are developed, researchers and others would typically examine previous studies to predict which factors may impact the adoption of the practices involved in the new policy. A problem might arise with this approach, as the primary focus of the previous studies in the literature was on profit-oriented practices. It could be that some of the factors that impacted the adoption of profit-oriented practices may not impact environment-oriented practices or there might be additional factors that may impact environment-oriented practices. Hence, the other objective of the dissertation was to identify similarities and dissimilarities between adoption of environment-oriented and profit-oriented practices. By doing that, it is expected that the policy makers and researchers will have better information about whether they need different policies for promoting adoption of environment-oriented practices or they can use the same policies as for promoting adoption of profit-oriented practices. This will then lead to better environmental policies.

In the current study, it was hypothesized that the difference between adoption of environment-oriented and profit-oriented practices would be due to perceptions of the farmers about the environmental impacts and about the profitability of the practices. Specifically, it was hypothesized that positive perceptions of the farmers about water quality effects would impact positively adoption of environment-oriented practices, but would not impact adoption of profit oriented practices. It was also hypothesized that positive perceptions of the farmers about the profitability of a practice would impact positively the adoption of a profit-oriented practice, but would have less of an impact on adoption of an environment-oriented practice.

Empirical results of the study showed evidence that adoption of environment-oriented practices is not impacted by positive attitudes of farmers about the water quality. However, adoption of both environment-oriented and profit-oriented practice were increased by positive perceptions of farmers about profitability of the practices. This result is also in line with the results from the off-farm income part of the dissertation. Hence, there is strong evidence that even positive attitudes about the environment would not lead to adoption of unprofitable practices. Policy makers should focus on the benefits of individual practices and make sure that farmers have full information about them. This result also showed the need for cost share and incentive programs for promoting adoption of environment-oriented practices, as farmers are not self motivated to adopt practices that conserve the environment but are not profitable for the farmer.

The current study found similarities between adoption of environment-oriented and profit-oriented practices and variables for education, farm sales and age of the farmers. It was also found that the type of manure handling system or the farming system is impacting both types of practices but the impact can be opposite. As far as the dissimilarities, off-farm income and government organizations are found to impact adoption of the profit oriented-practice but not the environment-oriented practice. Overall, there is evidence that factors that impact adoption of environment-oriented practices can be different than profit-oriented-practices, but there is further research needed to better identify the factors that impact adoption of environment-oriented practices.

Recommendations regarding development of new technologies should recognize that technologies need to be either profitable or profit-neutral if they are to be widely adopted without incentive payments. Technologies that are appropriate for different farming systems should also be encouraged since even in the Midwest there is a diversity of farming systems and farm sizes.

APPENDIX

A

Manure Management Survey

Farm operators should complete this questionnaire. (For the purposes of this questionnaire, a farm operator is someone who is currently farming and makes major decisions regarding the farm operation.) If you are not a farm operator, please give this questionnaire to the farm operator in your household. If there is no farm operator in your household, answer only question #1 and return the questionnaire in the business reply envelope provided.

1. **Are you a farm operator with livestock (other than for your own use)? (Check your answer.)**
   ☐Yes ☐No → STOP and return the blank questionnaire in the business reply envelope provided.

Section 1: Information about farming systems is useful in the design of programs.

2. On average, **HOW MANY** of the following livestock animals of all ages did you have on your farm at one time in 2005 (other than for your family's use)? Please write number of animals on the line.
   ________ Dairy cattle
   ________ Beef cattle on feed
   ________ Beef cows
   ________ Swine 55 lb or less
   ________ Swine more than 55 lb
   ________ Broilers
   ________ Turkeys
   ________ Other livestock (please list) __________________________

3. How many acres of land did you own in January 2005? (Please write the number of acres on the line.)
   ________ Acres (crop, pasture, and forest)

4. How many acres of land did you rent out to other farmers in 2005?
   ________ Acres

5. How many acres of land did you rent from others in 2005?
   ________ Acres (if None, please skip to question **#8**)

6. Do you apply manure or poultry litter to land that you rent from others? (Check the appropriate box.)
   ☐ Yes ☐ No

7. In the rental contract, are there clauses that specify required manure application practices?
   ☐ Yes ☐ No ☐ There is no written contract

8. In 2005, how many acres of the following crops did you have planted? (Please write number of acres)

   ☐ **I don't have crops**

   __________ Acres of corn
   __________ Acres of soybeans
   __________ Acres of wheat
   __________ Acres of alfalfa
   __________ Acres of other hay
   __________ Acres of pasture
   __________ Acres of other crop(s) (please list) ______________________

9. How many years have you been the primary farm operator?

   _________ Years

10. Please list the county (or counties) and state(s) where your farm is located.

    _______________________ County (or counties)
    _______________________ State (or states)

According to the Environmental Protection Agency (EPA), an animal feeding operation (AFO) is a lot or facility where the following conditions are met:

- Animals are stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and
- A ground cover of vegetation is sustained over less than 50% of the animal confinement area.

11. Could your farm be considered an animal feeding operation according to the definition above?

    ☐ Yes ☐ No

12. Are you a permitted concentrated animal feeding operation (CAFO)?

    ☐ Yes ☐ No

13. Is there a lake or stream on the land that you own?

    ☐ Yes ☐ No

14. My land is mostly (check one);

    ☐ flat
    ☐ rolling hills
    ☐ steep hills

15. Which of the following changes do you expect to occur on your farm in the next 5 years? (Please check one box in each row. N/A means not applicable to your farm.)

In the next 5 years do you expect...				
a. you or a family member will continue farming this farm.	☐ Yes	☐ No	☐ Not Sure	☐ N/A
b. to sell the farm	☐ Yes	☐ No	☐ Not Sure	☐ N/A
c. to increase livestock numbers	☐ Yes	☐ No	☐ Not Sure	☐ N/A
d. to expand crop acreage	☐ Yes	☐ No	☐ Not Sure	☐ N/A
e. to invest in new buildings on your farm	☐ Yes	☐ No	☐ Not Sure	☐ N/A

Section 2: There are several incentive programs available through USDA's Natural Resource Conservation Service (NRCS) and we are interested in awareness among the farm population of these programs and what can be done to improve the programs. We are also interested in the availability of private financing for equipment.

16. Are you aware of the Environmental Quality Incentives Program (EQIP)?
☐ Yes ☐ No (if No, please skip to question **#20**)

17. Do you currently have an EQIP contract through NRCS?
☐ Yes (if Yes, please skip to question **#20**) ☐ No

18. Did you apply for EQIP?
☐ Yes ☐ No

19. If you have not applied for EQIP, why not?

20. Have you prepared a Comprehensive Nutrient Management Plan (CNMP) following NRCS guidelines?
☐ Yes ☐ No (if No, please skip to question #**26**)

21. What year did you develop a CNMP?
_________ Year

22. Who prepared the CNMP?
☐ A private technical service provider
☐ NRCS staff
☐ Myself since I received CNMP training

23. If you used a technical service provider how much did it cost?
_________ dollars

24. How much time did you spend in meetings with NRCS staff or your technical service provider?
_________ days **OR** _________ hours

25. How much time did you spend on reading, paperwork and pulling together information for the CNMP?
_________ days **OR** _________ hours

26. In your experience, are banks willing to loan money to farmers for improving water quality?
☐ Yes ☐ No ☐ Don't know

27. Do you own equipment for injecting manure into the soil?
☐ Yes ☐ No (if No, please skip to question #**30**)

28. If you bought equipment for injecting manure into the soil, were you able to get a bank loan for it?
☐ Yes ☐ No ☐ Did not seek a bank loan

29. If you answered "Yes" to question **#28**, what percent of the cost was borrowed?
________%

30. Do you have an underground pipe system to move manure to some or all of your fields?
☐ Yes ☐ No (if No, please skip to question #**33**)

31. If you installed an underground piping system to move manure, were you able to get a bank loan for it?
☐ Yes ☐ No ☐ Did not seek a bank loan

32. If you answered "Yes" to question **#31**, what percent of the cost was borrowed?
_______%

<u>Section 3</u>: Questions about the use of manure as a fertilizer**.**

33. To how many acres of each crop do you apply manure?
☐ **I don't have crops**

________ Acres of corn
________ Acres of soybeans
________ Acres of wheat
________ Acres of oats
________ Acres of alfalfa
________ Acres of pasture/hay
________ Acres of another crop (please list) ____________________

34. Do you apply commercial fertilizer to any of your **manured** fields?
☐ Yes ☐ No

35. To what extent do you agree or disagree with the following statements? Please **circle** the number that best corresponds to your answer.

	Strongly Disagree		Neither Agree nor Disagree		Strongly Agree
a. The smell of manure bothers me or my family.	1	2	3	4	5
b. The smell of manure bothers my neighbors.	1	2	3	4	5
c. It is difficult to determine how much manure to apply to my crops, so I don't under or over apply nutrients.	1	2	3	4	5
d. Transportation costs and time affect which of my fields receive manure.	1	2	3	4	5
e. I'm not sure how my crops would respond to manure as compared to commercial fertilizer.	1	2	3	4	5
f. I am concerned about the water quality of streams and lakes in my county.	1	2	3	4	5
g. Properly managing manure improves water quality.	1	2	3	4	5
h. Agricultural regulations regarding water quality will become stricter in the next five years.	1	2	3	4	5

36. Have you provided manure to other farm operations or individuals in the past two years?
☐ Yes (if Yes, answer the following questions for the farm that received the most manure from you)
☐ No (if No, please skip to question #**44**)

37. What was the maximum distance the manure was transported?
About __________ Miles

38. Who applied the manure to the other farm?
a. ☐ Custom applicator
b. ☐ The farmer receiving the manure
c. ☐ I did
d. ☐ Other (please explain) ___________________________

39. Were you paid for the manure?
☐ Yes ☐ No (if No, please skip to question #**42**)

40. How much money did you receive for the manure? (Check one measurement or indicate other quantity.)
$_______ ☐ per ton? ☐ per acre? ☐ per pick-up load? ☐ per spreader load? ☐ per semi load?

41. Did this price include application of the manure?
☐ Yes ☐ No

42. Was there a written contract between you and the other farmer involved with the manure transfer?
☐ Yes ☐ No

43. Did either you or the farmer receiving the manure test the manure for nutrient content before applying it?
☐ Yes ☐ No ☐ I don't know

44. What type of manure storage facility do you have? (Check all that apply.)
   a. ☐ None
   b. ☐ Lagoon(s)
   c. ☐ Cement or glass-lined tank(s)
   d. ☐ Earthen basin(s)
   e. ☐ Stack house
   f. ☐ Other (please specify) ________________________

45. Which of the following structures and/or equipment do you use to manage manure? (Check all that apply.)
   a. ☐ Handle solid manure with a loader
   b. ☐ Scrape manure with a tractor
   c. ☐ Use a gutter scraping system
   d. ☐ Apply manure using a solids spreader
   e. ☐ Apply manure using a tank wagon
   f. ☐ Apply manure by an irrigation system
   g. ☐ Use traveling gun
   h. ☐ Use dragline injection system
   i. ☐ Other (please specify) ________________________

46. Given your typical livestock production, how many months of manure storage capacity do you have?
   a. ☐ 0-3 months
   b. ☐ 3-6 months
   c. ☐ 6-9 months
   d. ☐ 9-12 months
   e. ☐ More than 12 months

47. Did you hire a custom applicator to apply manure on your farm in the past two years?
☐ Yes ☐ No (If No, skip to question # **49**)

48. What was the cost of having them apply the manure? (Put price and check one measurement.)
$___________ ☐ per ton ☐ per acre ☐ per pick-up load ☐ per spreader load ☐ per semi load

49. What period(s) of the year did you apply manure in 2005? (Check all that apply)
   a. ☐ January-February
   b. ☐ March-April
   c. ☐ May-June
   d. ☐ July-August
   e. ☐ September-October
   f. ☐ November-December

50. Approximately how many hours per year do you spend applying manure?
   __________hours

51. How much influence does each of the following have on agricultural production decisions you make? (Please circle the number that best indicates the amount of influence.)

	None		Some		Very Much
a. Other farmers	1	2	3	4	5
b. Non-farming neighbors	1	2	3	4	5
c. Banking/Lending institutions	1	2	3	4	5
d. Contractors / Integrators	1	2	3	4	5
e. University	1	2	3	4	5
f. NRCS	1	2	3	4	5
g. Other government organizations	1	2	3	4	5

The following questions regarding manure management activities are very important to this study. Please answer them as completely and carefully as possible. Remember, only completed questionnaires will be considered for the Wal-Mart gift certificate drawing.

52. Please give your opinion regarding the following characteristics of the given practices even if you don't perform them. (**Circle** the number that best corresponds to your opinion about each of the characteristics.)

	Strongly Disagree		Neither Agree nor Disagree		Strongly Agree
Use this scale when answering the questions:	**1**	**2**	**3**	**4**	**5**

Practice	This is a profitable practice, it improves my bottom line	This practice improves water quality.	This practice is time consuming.	This practice is complicated.
a. Use Round-up Ready soybeans	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
b. Use phytase in my feed rations	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
c. Test soil for nutrients at least every THREE years.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
d. Test manure for nutrients at least annually	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
e. Maintain a setback between streams and lakes and manure application areas of 100 feet	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
f. Inject manure into the soil during application	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
g. Calibrate manure spreaders at least annually	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
h. Keep detailed records on what day, how much and to what field manure was applied	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
i. Use a grass filter system as a buffer around water sources	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
j. Use an underground pipe system to move manure to some or all your fields	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

53. **Again, these questions are important to this study so please answer them and the questions on the following page as completely as you can.**
- Please check Yes or No in questions (A) and (C).
- In questions (B) and (D), please write the relevant years in the blanks.

Practice	(A) Do you perform the practice?	(B) If you currently do the practice, when did you start doing it?	(C) If you don't currently do the practice, have you done it in the past?	(D) If you answered yes to question (C), what year did you start and end doing the practice?
a. Use Round-up Ready soybeans	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
b. Use phytase in my feed rations	☐Yes ☐No ☐Don't know	Year_____	☐ Yes ☐ No	Start_____ End _____
c. Test soil for nutrients at least every THREE years.	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
d. Test manure for nutrients at least annually	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
e. Maintain a setback between streams and lakes and manure application areas of 100 feet	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
f. Inject manure into the soil during application	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
g. Calibrate manure spreaders at least annually	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
h. Keep detailed records on what day, how much and to what field manure was applied	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
i. Use a grass filter system as a buffer around water sources	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____
j. Use an underground pipe system to move manure to some or all your fields	☐ Yes ☐ No	Year_____	☐ Yes ☐ No	Start_____ End _____

➔ **Over to last page**

Section 4: Off-farm employment is important for many farmers and may have an impact on the farming operation. Please answer the following questions for 2005.

54. Please check your answer for questions **a** and **b** and write the relevant hours for question **c**.

	Farm Operator	**Spouse** ☐Not Applicable	**Other Family Member #1** ☐Not Applicable	**Other Family Member #2** ☐Not Applicable
a. Contributes significantly to farm work	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
b. Has off-farm work (check one box per person)	☐ none ☐ seasonal ☐ year round	☐ none ☐ seasonal ☐ year round	☐ none ☐ seasonal ☐ year round	☐ none ☐ seasonal ☐ year round
c. Hours per week worked off the farm	______hours per week (during the weeks worked)	______hours per week (during the weeks worked)	______hours per week (during the weeks worked)	______hours per week (during the weeks worked)

55. Does your off-farm work interfere with the timing of your farming operations?
☐ Yes ☐ No (if No, please skip to question #**57**) ☐ Not applicable

56. What periods and activities cause severe time crunch problems? (Check the **two** worst problems.)
a. ☐ Planting in spring
b. ☐ Fall harvest
c. ☐ Cleaning out livestock facilities
d. ☐ Haying
e. ☐ Timing of manure applications
f. ☐ Other __________________

57. Did you hire non-family farm labor in 2005?
☐ Yes ☐ No

58. What is your household's annual **off-farm** gross income?
a. ☐ No off-farm income
b. ☐ Between $0 and $9,999
c. ☐ Between $10,000 and $24,999
d. ☐ Between $25,000 and $49,999
e. ☐ Between $50,000 and $99,999
f. ☐ $100,000 or more

59. What amount of gross farm sales did you have in 2005?
a. ☐ Between $0 and $9,999
b. ☐ Between $10,000 and $99,999
c. ☐ Between $100,000 and $249,999
d. ☐ Between $250,000 and $499,999
e. ☐ $500,000 or more

60. What is the highest level of education you have completed?
   a. ☐ Less than High School
   b. ☐ High School
   c. ☐ Some college or vocational school
   d. ☐ Bachelor's degree
   e. ☐ Graduate degree, such as Master's

61. What year were you born? _________________

Thank you for your participation. Feel free to use the space below or above right to write any comments you have about the questionnaire or manure issues in general. Then, return the questionnaire in the business reply envelope.

B

Table 34: Results of the Univariate Probit Regressions

Variable	**Inject Manure**		**Grass Filter**		**Soil Testing**		**Record Keeping**	
	Coeff.	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**	**Coeff.**	**p-value**
Age	0.14	-0.05	-0.09	0.05	-0.17	0.00	0.01	0.83
Age^2	0.00	0.00	0.00	0.09	0.00	0.01	0.00	0.71
Iowa	1.05	0.31	0.02	0.89	0.55	0.00	0.25	0.21
Education								
Less than High School	-2.29	-4.03	-0.56	0.06	-0.35	0.25	-0.16	0.64
Some College or Vocational School	0.07	-0.55	-0.25	0.13	-0.13	0.50	0.34	0.06
Bachelor Degree	0.63	-0.07	-0.06	0.76	0.03	0.88	0.16	0.48
Graduate Degree			-0.15	0.79	0.10	0.85		
Off-farm Income								
None	-0.03	-1.07	-0.01	0.96	0.43	0.19	0.37	0.28
$0 - $9,999	0.91	0.02	-0.44	0.08	-0.02	0.95	0.38	0.16
$25,000 - $49,999	-0.50	-1.39	-0.53	0.02	-0.09	0.73	-0.09	0.69
$50,000 - $99,999	-0.19	-1.21	-0.22	0.47	-0.23	0.49	-0.03	0.92
$100,000 +	0.59	-1.07	-0.65	0.22	-1.05	0.03	-0.36	0.60
Contributes Significantly to Farm Work								
Spouse	0.19	-0.38	-0.18	0.26	-0.18	0.28	-0.03	0.86
Other Family Member	0.41	-0.22	0.23	0.12	0.11	0.50	-0.30	0.07
Off-Farm Work								
Farm Operator Seasonal	0.93	0.33	0.15	0.47	0.53	0.07	-0.04	0.86
Farm Operator Year Round	1.38	0.32	0.05	0.84	-0.08	0.75	-0.12	0.65
Spouse Seasonal	-0.85	-1.92	0.14	0.66	1.21	0.00	-0.03	0.93
Spouse Year Round	0.25	-0.57	0.10	0.66	0.68	0.01	0.10	0.68
Off-farm work interfere								
Yes	-0.35	-1.16	0.36	0.11	0.16	0.50	0.14	0.54
Not Applicable	-0.09	-0.73	-0.25	0.16	-0.05	0.83	-0.22	0.25
Hire Non-Farm Labor	0.14	-0.43	-0.05	0.72	0.17	0.31	0.16	0.30
Farm Sales								
$10,000 - $99,999	-0.84	-1.67	-0.36	0.04	-0.39	0.06	-0.03	0.88
$250,000 - $499,999	0.27	-0.43	0.17	0.38	0.07	0.77	0.01	0.96
$500,000 +	1.40	0.45	0.60	0.03	0.17	0.60	0.14	0.60
Smell of Manure Bothers Me or My Family								
Disagree	1.26	0.35	-0.25	0.30	-0.70	0.01	0.04	0.88
Neutral	0.29	-0.45	-0.26	0.24	-0.45	0.05	-0.09	0.71
Smell of Manure Bothers My Neighbors								
Disagree	-0.87	-1.76	0.14	0.52	-0.03	0.89	-0.25	0.34
Neutral	0.56	-0.10	0.19	0.32	0.24	0.22	0.02	0.94
Not Sure How Crops Respond to Manure								
Disagree	0.17	-0.64	0.22	0.32	0.52	0.04	0.16	0.52
Neutral	0.65	-0.23	-0.12	0.63	0.19	0.48	0.04	0.90

Table 34: Results of the Univariate Probit Regressions (Continued)

Variable	Inject Manure		Grass Filter		Soil Testing		Record Keeping	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Concerned about the Water Quality								
Disagree	0.65	-0.47	0.01	0.99	0.48	0.14	-0.57	0.14
Neutral	1.00	0.17	0.11	0.68	-0.36	0.16	-0.18	0.50
Managing Manure Improves Water Quality								
Disagree	1.03	-0.35	0.21	0.63	0.41	0.36	0.78	0.08
Neutral	-0.65	-1.68	0.23	0.35	0.00	0.99	0.04	0.87
Regulations will be Stricter								
Disagree	-2.03	-4.27	-0.22	0.63	0.48	0.21	-0.77	0.26
Neutral	0.58	-0.13	0.13	0.49	-0.06	0.75	0.16	0.41
Transportation Costs and Time Affect Which of My Fields Receive Manure								
Disagree	0.14	-0.45	0.15	0.34	0.64	0.00	0.33	0.07
Neutral	0.01	-0.66	-0.46	0.02	0.35	0.08	0.15	0.51
Continue Farming								
Yes	-1.01	-2.40	-0.09	0.80	0.52	0.18	0.47	0.22
Not Sure	0.87	-0.56	-0.32	0.45	-0.04	0.93	-0.15	0.77
Expand Livestock Numbers								
Yes	-0.42	-1.21	-0.25	0.15	0.30	0.13	-0.21	0.27
Not Sure	-0.61	-1.22	-0.13	0.48	0.11	0.60	-0.09	0.63
Profitable								
Disagree	-2.08	-3.17	-1.26	0.00	-1.36	0.00	-1.16	0.00
Neutral	-1.69	-2.53	-0.91	0.00	-1.22	0.00	-0.59	0.00
Improves Water Quality								
Disagree	-1.37	-2.31	0.00	0.99	0.55	0.16	0.13	0.63
Neutral			-0.63	0.00	-0.13	0.51	-0.42	0.03
Time Consuming								
Disagree	0.40	-0.44	0.18	0.45	0.02	0.91	0.95	0.00
Neutral	0.15	-0.42	-0.26	0.19	-0.33	0.08	0.32	0.11
Complicated								
Disagree	1.25	0.40	0.47	0.08	0.56	0.02	0.21	0.40
Neutral	0.46	-0.38	0.34	0.17	0.29	0.28	0.08	0.70
EQIP	-1.05	-1.90	0.09	0.67	0.25	0.25	0.22	0.24
Manure Handling								
Solid	-3.64	-4.97	0.35	0.21	0.09	0.79	-1.24	0.00
Solid and Liquid	-0.96	-1.91	0.21	0.42	0.06	0.86	-1.00	0.00
Total Animal Units	0.00	0.00	0.00	0.91	0.00	0.06	0.00	0.05
Species Dummy								
Dairy	-0.96	-1.88	-0.24	0.31	0.16	0.55	-0.28	0.30
Beef Cow	-0.52	-1.27	-0.26	0.27	0.78	0.01	-0.41	0.12
Beef Cattle	-2.11	-3.53	-0.05	0.85	0.69	0.02	-0.47	0.13
Poultry	-1.11	-2.49	-0.16	0.67	0.26	0.53	0.43	0.35
Turkey	0.56	-0.48	0.05	0.90	0.30	0.43	0.71	0.05
Other	0.14	-1.72	0.04	0.94	-0.20	0.72	0.98	0.05
Constant	-3.07	-8.71	3.69	0.01	3.12	0.08	-0.42	0.78

BIBLIOGRAPHY

Abdulai, A., and Huffman, W. E., (2005). "The Diffusion of New Agricultural Technologies: The Case of Crossbred-Cow Technology in Tanzania." *American journal of Agricultural Economics*, 87(3), 645-659.

Ahearn, M. C., and El-Osta, H. S. (1993). "The Role of Off-farm Employment: Permanent or Transitional State." *Selected Paper for Presentation at the American Agricultural Economics Association Annual Meeting,* Baltimore, Maryland, August.

Aillery, M., Gollehon, N., Johansson, N., Kaplan, J., Key, N., and Ribaudo, M. (2005). "Managing Manure to Improve Air and Water Quality." Economic Research Report Number 9, U.S. Department of Agriculture, Economic Research Service, September.

Barham, B. L., Foltz, J. D., Smith, D. J., and Moon, S. (2004). "The Dynamics of Agricultural Biotechnology Adoption: Lessons from rBST Use in Wisconsin, 1994-2001." *American Journal of Agricultural Economics,* 86(1): 61-72.

Barlett, P. F. (1996). "Part-Time Farming: Saving the Farm or Saving the Life-Style." *Rural Sociology,* 51(3), 289-313.

Bartenhagen, K. A., Marjut, H. T., and Osmond, D.L. (1994). "Information from the Water Quality and Land Treatment Education Component of Water, Soil, and Hydro-Environmental Decision Support System." North Carolina State University Water Quality Group, August.

Bharadwaj, L., and Findeis, J. L. (2003). "Off-farm Work Among Farm Women: Motivations, Earnings, and Benefit Receipt." *Selected Paper for Presentation at the American Agricultural Economics Association Annual Meeting,* Montreal, Canada, July 27-30.

Carey, J. M., and Zilberman, D. (2002) "A Model of Investment Under Uncertainty: Modern Irrigation Technology and Emerging Markets in Water." *American Journal of Agricultural Economics*, 84(1), 171-183.

Chang, H. H., and Boisvert, R. N. (2005) "Are Farmers' Decisions to Work off the Farm and Participate in the Conservation Reserve Program Independent, Joint or Sequential?" *Selected Paper for Presentation at the American Agricultural Economics Association Annual Meeting,* Providence, Rhoe Island, July 24-27.

Cornejo, F. J., Hendricks C., and Mishra, A. (2005). "Technology Adoption and Off-farm Household Income: The Case of Herbicide-Tolerant Soybeans." *Journal of Agricultural and Applied Economics*, 37(3), 549-563.

Couvillion, C. W., Kari, F., Hudson, D., and Allen, A. (2000). "A Preliminary Economic Assessment of Roundup Ready Soybeans in Mississippi." Mississippi State University, Research Report 2000-005. http://ageconsearch.umn.edu/bitstream/15783/1/rr00-005.pdf

Cox, W. E. Jr. (1967). "Product Life-Cycles as Marketing Models." *The Journal of Business*, 4, October, 375-384.

Cromley, S., and Lory, J. (2006). "Setback Distances for Land Application of Manure." University of Missouri – Columbia Extension. http://extension.missouri.edu/explore/agguides/soils/g09219.htm

Dillman, D. A. (2000). *Mail and Internet Surveys: The Tailored Design Method*, John Wiley & Sons, Inc., New York.

Dixit, A., and Pindyck R. (1994) *Investment Under Uncertainty*, Princeton University Press, Princeton.

Dorfman, J. H. (1996). "Modeling Multiple Adoption Decisions in a Joint Framework." *American Journal of Agricultural Economics*, 78, 547-557.

Environmental Protection Agency. (1998). "National Water Quality Inventory: 1996 Report to Congress." EPA841-R-97-008, Washington, DC.

Environmental Protection Agency. (2006). "Ag 101." http://www.epa.gov/oecaagct/ag101/index.html

Feder, G. (1980). "Farm Size, Risk Aversion and the Adoption of New Technology Under Uncertainty." *Oxford Economic Papers*, Vol 32.

Feder, G., and O'Mara, G. T. (1981). "Farm Size and the Diffusion of Green Revolution Technology." *Economic Development and Cultural Change*, 30, 59-76.

Feder, G., and O'Mara, G. T. (1982). "On Information and Innovation Diffusion: A Bayesian Approach." *American Journal of Agricultural Economics*, 64, 141-145

Feder, G., and Slade, R. (1984). "The Acquisition of Information and Technology Adoption." *American Journal of Agricultural Economics*, 66(3), 312-320.

Feder, G., Just, R. E., and Zilberman, D. (1985). "Adoption of Agricultural Innovations in Developing Countries: A Survey." *Economic Development and Cultural Change,* 33(2), 255-298.

Fulhage, C. D, (1994a). "Calibrating Manure Spreaders." University of Missouri – Columbia Extension. http://extension.missouri.edu/explore/envqual/wq0213.htm

Fulhage, C. D, (1994b). "Record Keeping for Manure Land Application." University of Missouri – Columbia Extension. http://extension.missouri.edu/explore/envqual/wq0218.htm

Fulhage, C. D, (2000). "Laboratory Analysis of Manure." University of Missouri – Columbia Extension. http://extension.missouri.edu/xplor/envqual/eq0215.htm

Fulhage, C. D, and Pfost, L. D. (1994). "Spreading Poultry Litter with Lab Analysis and with Soil Tests." University of Missouri – Columbia Extension. http://extension.missouri.edu/explore/envqual/wq0223.htm

Fulhage, C. D, and Pfost, L. D. (2001). "Swine Manure Management Systems in Missouri." University of Missouri – Columbia Extension. http://extension.missouri.edu/xplor/envqual/eq0350.htm

Fulhage, C. D, and Pfost, L. D. (2003). "Economic Considerations for Beef Manure Management Systems." University of Missouri – Columbia Extension. http://extension.missouri.edu/explore/envqual/eq0392.htm

Gollehon, N., Caswell, M., Ribaudo, M., Kellogg, R., Lander, C., and Letson, D. (2001). "Confined Animal Production and Manure Nutrients."AIB-771, U.S. Department of Agriculture, Economic Research Service, June.

Goodwin, B.K. and Bruer, S. M. (2003) "An Empirical Analysis of Farm Structure and Off-Farm Work Decisions." *Selected Paper for Presentation at the American Agricultural Economics Association Annual Meeting,* Montreal, Canada, July 27-30.

Greene, W. H. (2003). *Econometric Analysis*, Prentice-Hall Inc., New York.

Griliches Z. (1957). "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica,* 25(4), 501-522.

Hallberg, M. C., Findeis, J. L., and Lass, D. A. (1991). *Multiple Job-Holding Among Farm Families*, Iowa State University Press, Ames, Iowa.

Hayami, Y., and Ruttan, V. W. (1971). *Agricultural Development: An International Percpective*, John Hopkins University Press, Baltimore.

Hernes, G. (1976). "Diffusion and Growth: the Non-homogeneous Case." *Scandinavian Journal of Economics*, 78, September, 427-36.

Hiebert, L. D. (1974). "Risk, Learning, and the Adoption of Fertilizer Responsive Seed Varieties." *American Journal of Agricultural Economics*, 56, 764-768

Hoppe, A. R., and Banker, E. D. (2006). "Structure and Finances of U.S. Farms: 2005 Farm Family Report." Economic Information Bulletin Number 12, U.S. Department of Agriculture, Economic Research Service, May.

Horton, J. N., and Kleinman, P. K. (2007). "Much Ado About Nothing: A Comparison of Missing Data Methods and Sofware to Fit Incomplete Data Regression Models." *The American Statistician,* February, Vol. 61, No. 1.

Hua W., Zulauf, C., and Sohngen, B. (2004). "To Adopt or Not to Adopt: Conservation Decisions and Participation in Watershed Groups." *Selected Paper for Presentation at the American Agricultural Economics Association Annual Meeting,* Denver, Colorado, July 1-4.

Huffman, W. E. (1974). "Decision making: The Role of Education." *American Journal of Agricultural Economics*, 56, 85-97.

Huffman, W. E. (1980). "Farm and Off-Farm Work Decisions: The Role of Human Capital." *The Review of Economics and Statistics,* 62(1), 14-23.

Huffman, W. E. (1977). "Allocative Efficiency: The Role of Human Capital." *The Quarterly Journal of Economics,* 91(1), 59-79.

Huffman, W. E. and Lange, M. D. (1989). "Off-Farm Work Decisions of Husbands and Wives: Joint Decision Making." *The Review of Economics and Statistics*, 71(3), 471-480.

Huisman, M. (2000). "Imputation for Missing Item Responses: Some Simple Techniques." *Quality and Quantity*, 34, 331-351.

Iowa State University. (2003). "CNMP Core Curriculum." http://www.abe.iastate.edu/wastemgmt/cnmp-curriculum.html#c7513

Just, R. E. and Zilberman, D. (1988). "The Effects of Agricultural Development Policies on Income Distribution and Technological Change in Agriculture." *Journal of Development Economics,* 28, 193-216.

Just, R. E., and Zilberman, D. (1983). "Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture." *Oxford Economic Papers,* 35, 307-328.

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), 35-51.

Koundouri, P., Nauges, C., and Tzouvelekas, V. (2006). “Technology Adoption Under Production Uncertainty: Theory and Application to Irrigation Technology.” *American Journal of Agricultural Economics*, 88(3), 657-670.

Lehvall, P. and Wahlbin, C. (1973). “A Study of Some Assumptions Underlying Innovation Diffusion Functions.” *Swedish Journal of Economics*, 75, 362-377.

Mansfield, E. (1961). “Technical Change and the Rate of Imitation.” *Econometrics*, 29, October, 741-65.

Mansfield, E. (1963). “The Speed of Response of Firms to New Techniques.” *Quarterly Journal of Economics*, 77, 290-311.

Mas-Colell, A., Whinston, M. D., and Green, J. R. (1995). *Microeconomic Theory*, Oxford University Press, New York.

Mishra, A. K., and Goodwin, B. K. (1997). “Farm Income Variability and Supply of Off-farm Labor.” *American Journal of Agricultural Economics*, 79, 880-887.

Mishra, A. K., El-Osta, H. S., Morehart, M. J., Johnson, J. D., and Hopkins J. W. (2002). “Income, Wealth, and the Economic Well-Being of Farm House-holds.” Agricultural Economic Report 812, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

Monsanto. (2006). “Roundup Ready Soybeans.” http://www.monsanto.ca/_pdfs/seeds_traits/rrsoybeanbro.pdf

Moreno, G., and Sunding, D. L. (2005). “Joint Estimation of Technology Adoption and Land Allocation with Implications for the Design of Conservation Policy.” *American Journal of Agricultural Economics*, 87(4), 1009-1019.

Missouri Department of Agriculture. (2008). “Weekly Market Summary.” http://www.ams.usda.gov/marketnews.htm

Mitchell, N. M. (2006). “Strategically Using General Purpose Statistics Packages: A Look at Stata, SAS and SPSS.” UCLA Academic Technology Services, Technical Report Series, Report Number 1, Version Number 1.

Musil, M. C., Warner, B. C., Yobas, K. P., and Jones, L.S. (2002). “A Comparison of Imputation Techniques for Handling Missing Data.” *Western Journal of Nursing Research*, 24(7), 815-829.

Muthia, C. (1971). "The Green Revolution: Participation by Small versus Large Farmers." *Indian Journal of Agricultural Economics*, 26, 25-34.

Nakao, M., Sohngen, B., Brown, L., and Leeds, R. (1999). "The Economics of Vegetative Filter Strips." Ohio State University Extension, AE-0006-99.

National Health and Nutrition Examination Survey III. (2001). "Multiply Imputed Data Set User's Guide." June.

Pfost, L. D., Fulhage, D. C., and Alber, O. (2001). "Land Application Equipment for Livestock and Poultry Manure Management." University of Missouri – Columbia Extension. http://extension.missouri.edu/xplor/envqual/eq0383.htm

Pfost, L. D., Fulhage, D. C., and Rastorfer. D. (2000). "Beef Manure Management Systems in Missouri." University of Missouri – Columbia Extension. http://extension.missouri.edu/explore/envqual/eq0377.htm

Pfost, L. D., and Fulhage, D. C., and Rastorfer. D. (2004). "Dairy Waste Management Systems in Missouri." University of Missouri – Columbia Extension. http://extension.missouri.edu/explore/envqual/eq0301.htm

Prairie Agricultural Machinery Institute. (1997). "A Guide to Pipeline Manure Injection Systems." http://www.pami.ca/pdfs/reports_reasearch_updates/729_pipeline_manure_injection_systems.pdf

Qaim, M., and de Janvry, A. (2003). "Genetically Modified Crops, Corporate Pricing Strategies, and Farmers' Adoption: The Case of Bt Cotton in Argentina." *American Journal of Agricultural Economics*, 85(4), 814-828.

Rahm M. R., and Huffman W. E. (1994). "The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables." *American Journal of Agricultural Economics*, 66, 405-413

Rogers, E. M. (2003). *Diffusion of Innovations*, The Fee Press, New York.

Roumasset, J. A. (1976). *Rice and Risk: Decision Making among Low-Income Farmers*, North-Holland Publishing Co., Amsterdam.

Schluter, M. (1971). "Differential Rates of Adoption of the New Seed Varieties in India: The Problem of Small Farms." U.S. Agency for International Development, Occasional Paper no. 47, Cornell University, Ithaca, New York.

Schultz, T.W. (1975). "The Value of the Ability to Deal with Disequilibria." *Journal of Economic Literature,* 13(3), 827-846.

Soule, M.J., Tegene, A., and Wiebe, K. D. (2000). "Land Tenure and the Adoption of Conservation Practices." *American Journal of Agricultural Economics*, 82(4), 993-1005.

StataCorp. (2005). *Stata Statistical Software: Release 9*. College Stattion, TX: Stata Corp LP.

Sunding, D., and Zilberman, D. (2001). "The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector." Handbook of Agricultural Economics, B. L. Gardner and G. C. Rausser, eds., Elsevier, Amsterdam, 207-261.

Sydorovych, O., and Marra, M. (2008). "Valuing the Changes in Herbicide Risks Resulting from Adoption of Roundup Ready Soybeans by U.S. Farmers: An Empirical Analysis of Revealed Value Estimates." *Selected Paper for Presentation at the Southern Agricultural Economics Association Annual Meetings,* Dallas, Texas, February 2-5.

Tokle, J. G., and Huffman, W. E. (1991). "Local Economic Conditions and Wage Labor Decisions of Farm and Rural Nonfarm Couples." *American Journal of Agricultural Economics*, 73, 52-70.

U.S. Department of Agriculture. (1996). "Agricultural Waste Management Field Handbook." http://www.info.usda.gov/CED/ftp/CED/neh651-ch13.pdf

U.S. Department of Agriculture. (2006). "Commodity Costs and Returns: U.S. and Regional Cost and return Data." http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm

U.S. Department of Agriculture and Environmental Protection Agency. (1999). "Unified National Strategy for Animal Feeding Operations."

U.S. Department of Agriculture and Natural Resources Conservation Service. (2003). "National Planning Procedures Handbook." http://www.abe.iastate.edu/fileadmin/www.abe.iastate.edu/extension/wastemgmt/CNMP_Curriculum/H_180_600_E_54.pdf

U.S. Department of Interior. (1999). "The Quality of Our Nation's Waters: Nutrients and Pesticides." U.S. Geological Survey Circular 1225.

Upadhyay, B. M., Young D. L., Wang H. H., and Wandschneider, P. (2002). "How Do Farmers Who Adopt Multiple Conservation Practices Differ From Their Neighbors?" *Selected Paper for Presentation at the American Agricultural Economics Association Annual Meeting,* Long Beach, California, July 28-31.

Welch, F. (1970). “Education in Production.” *Journal of Political Economy*, 78, 35-59.

Wooldridge, M. J. (2006). *Introductory Econometrics* , Thomson South-Western, USA.

Wozniak, G. D. (1984). “The Adoption of Interrelated Innovations: A Human Capital Approach.” *The Review of Economics and Statistics*, 66(1), 70-79

Wozniak, G. D. (1987). “Human Capital, Information, and the Early Adoption of New Technology.” *The Journal of Human Resources,* 22(1), 101-112.

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