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Factors affecting adoption of cover crops and its effect on nitrogen use by producers

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FACTORS AFFECTING ADOPTION OF COVER CROPS AND ITS EFFECT ON NITROGEN USE BY PRODUCERS

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ABSTRACT

Increasing environmental concerns, population, and changing preferences of consumers towards healthier foods, and agronomic practices have all aligned to provide not only food and fiber, but also sustainable practices useful to the environment. Cover crops, a type of agricultural technology, provide private and public benefits, which are vital for organic production.

The objectives of this study are: 1) Identify determinants of cover crop adoption; 2) analyze how nitrogen management varies by farm relative to adoption or non-adoption of this technology; 3) estimate the change in the probability of adoption of cover crops due to farm, regional and operator characteristics by non-adopters; and 4) estimate the change in intensity in nitrogen use by cover crop adopters due to farm, regional, and operator characteristics.

To address our objectives, we developed a two-stage simultaneous equation model where the first stage provides information on the factors affecting adoption of cover crops using a probit model. To better understand the effects of cover crops on the amount of nitrogen use by producers we use a left-censored tobit model and incorporated the adoption of cover crops as an endogenous variable. To estimate the intensity of the effect of adoption of cover crops, we used the McDonald and Moffitt (1980) decomposition of the marginal effects.

The results of the probit model showed that producer's age, experience, experience squared, all conservative payments, using other producers (who grow cover crops) and organic fertilizer dealers as information sources when making nitrogen management decisions had a significant effect on cover-crop adoption. The results of the tobit model showed econometrically that cover crop adoption had a significant effect on nitrogen use by producers. Three other variables that had a significant effect on nitrogen use by producers were field slope of 12% or more, rented field, and off-farm work.

CHAPTER 1: INTRODUCTION

1.1. AGRICULTURAL ENVIRONMENT

As population has increased and technologies have changed over time, agricultural practices provide not only food and fiber to consumers but also certain practices, that can create environmental degradation, like land erosion, nitrogen leaching to water sources, other types of water pollution, and losses of CO_2 because of deforestation to convert forests to agricultural land (Tinker et al. 1996). And, of course, climate-change issues have become very important recently, with focus being directed at agriculture as a potential source for greenhouse gas mitigation through carbon sequestration, among others.

Rural and urban populations often value agricultural land as open space and as a source of countryside amenities. Agricultural land is frequently a habitat for wildlife species. The agricultural sector can contribute to economic viability of many rural areas and to food security. On the other hand, conversion of forests and wetlands to agricultural production can damage ecosystems. Agricultural nutrients, pesticides, pathogens, salts, and eroded soils are leading causes of water quality problems in many countries. Part of the water used for irrigation in agriculture is water unavailable to nonagricultural sectors or ecosystems (Abler, 2004).

1.2. MULTIFUNCTIONAL AND ORGANIC AGRICULTURE

With increasing environmental concerns, increasing population, changing tastes and preferences of consumers towards healthier foods, and more food-safety requirements, agronomic practices have changed gradually to provide not only food and fiber but also public goods and other beneficial services from agriculture. Besides producing private (food and fiber) and industrial (bioenergy) goods, agriculture can provide many public goods and services or positive externalities such as land conservation, maintenance of landscape structure, biodiversity preservation, nutrient recycling and loss reduction, among others (Boody et al. 2005; Yrjola and

Kola 2004).

The term multifunctionality or “multifunctional agriculture” first was created in the European Union, in the late 1990s (Abler, 2004; Durand and Van Huylebroeck, 2003). Nowadays, multifunctional agriculture is one of the key issues and concepts in European agriculture and in the public agricultural policy (Yrjola and Kola 2004). Agronomic practices that provide public goods and other beneficial services, as well as agricultural products, are referred to as multicultural agriculture – a foundation for the European model of agriculture and agricultural policy (Batie 2003). In recent years, the role of multifunctional agriculture has broadened to include meeting the needs of an increasing population and to provide sustainable practices that benefit and to not degrade the environmental amenities, society enjoys.

The elements of multifunctional agriculture are positive externalities (e.g. decreased nitrogen leakage using cover crops) and, in most common cases, public goods that are produced jointly with food or fiber in an agricultural process. Therefore, these external effects do not have definable monetary value and no compensation is paid in producing them (Yrjola and Kola 2004). Importantly, realizing these external outcomes has gained momentum in EU member states around the concept of multifunctionality. Multifunctionality denotes the output by agricultural businesses of multiple goods, products, and services that go beyond conventional commodity production (OECD, 2001).

Different authors have various definitions of multifunctional agriculture. Abler (2004) defines the term multifunctionality as an agricultural activity that can have multiple outputs and therefore may contribute to several objectives at once. Yrjola and Kola (2004) defined multifunctional agriculture as agricultural production processes producing not only food and fiber but also various kinds of non-market, non-commodity outputs, which include, in the broadest sense, the impacts of agriculture on the state of the environment in rural areas, rural landscape, biodiversity on and close to farmland, contribution of agriculture to socio-economic viability of the countryside, food safety, national food security, welfare of production animals, and cultural and historical heritage.

Clark (2004) defines multifunctionality as the multiple positive contributions that agriculture can make to economies, environmental management, and the viability of rural economies for regional economic development. Finally, according to Moran et al. (2006), multifunctional agriculture attempts to establish a new balance between commodity support and services that are increasingly demanded by the public.

The Northeastern region of the United States has shown an increased interest in multifunctional attributes from agriculture. According to Batie (2003), this interest is predictable: as income rises, multifunctional attributes are increasingly valued (i.e., the income elasticity for multifunctional attributes is higher than that of traditional food and fiber). Furthermore, the more populated regions of the country are most concerned with protecting multifunctional rural amenity attributes (Hellerstein et al., 2002).

Other widely known advantages of multifunctional agriculture, as formed by Boody et al. (2005) are that environmental and economic benefits can be attained through changes in agricultural land management without increasing public costs (like more diverse rotations, perennial buffers along rivers and streams, and cover crops). Environmental benefits include improved water quality, healthier fish, increased carbon sequestration, and decreased greenhouse gas emissions, while economic benefits include social capital formation, greater farm profitability, and unincurred costs.

Organic farming is only one of the parts of multifunctional agriculture (Dabberts et al., 2004, and Brozova, 2005). While multifunctional agriculture tries to use positive externalities of agricultural production, organic farming tries to produce organic products relying on ecologically based practices without using any synthetic chemicals in crop production and with prohibition of antibiotics and hormones in livestock production (Dimitri and Greene, 2002).

In recent years there has been an increase towards environmental concerns, and there has also been continuing concern over the movement of fertilizer nutrients to ground and surface waters with possible eutrophication and public health consequences (Klepper et al., 2001). Organic farming was created to capture and protect the environmental benefits of agricultural systems (Greene and Kremen, 2002).

The term "organic farming" first came into use in the United States in the 1940s; however, organic crop production did not begin to really develop as an industry until the 1970s (University of Kentucky/CES, 2007). Organic farming, which is also known as "natural farming" or "biological farming", is an alternative agricultural system that does not rely on chemical fertilizer or pesticides. In this system, plant nutrients are supplied through organic wastes (particularly livestock manures) and leguminous green manures (cover crops) (Klepper et al. 2001).

Planting cover crops, cultivating, composting, irrigating and using animal and green manures are also employed in organic systems (University of Kentucky/CES, 2007). Soil fertility and crop nutrients are managed through tillage and cultivation practices, crop rotations, and cover crops, supplemented with manure and crop waste material and allowed synthetic substances (Dimitri and Greene, 2002).

Conversion from conventional to organic production is relatively risky; only land that has been free of prohibited substances (e.g. synthetic pesticides and artificial fertilizers) for 3 years can be certified for organic production (Greene and Kremen, 2002, and University of Kentucky/CES, 2007). Obstacles to adoption include large managerial costs and risks of shifting to a new way of farming, as well as limited awareness of organic farming systems (Greene and Kremen, 2002).

As it is not allowed to use synthetic pesticides and artificial fertilizers, soil fertility is enhanced through cover crops, nitrogen-fixing legumes, green manure, animal manure, and approved natural fertilizers. There are no restrictions regarding the source of manure; however, the National Organic Program does regulate the application of raw manure (University of Kentucky/CES, 2007). Livestock manure is traditionally a key fertilizer in organic and sustainable soil management. It is most effectively used in combination with other sustainable practices such as crop rotation and cover cropping, among others (Kuepper, 2003).

In comparing organic and conventional cropping systems, it has been found that yields of crops in full organic production may be somewhat lower (5 to 10 percent) than that of conventional production. Most often cited are yield reductions of approximately 5 to 10 percent; however, in some studies these reductions were higher. A recent study of corn and soybean production in Iowa found that organic farms had lower fertilizer and pesticide costs, but higher seed and machinery costs (University of Kentucky/CES, 2007).

Though adoption of organic farming requires more labor intensive inputs than conventional farming (University of Kentucky/CES, 2007), higher marginal cost, lower yields, and its adoption is associated with uncertainty, it has also been concluded that it can be very profitable as well. Organic foods are typically more expensive than conventional foods, costing at least 10 to 30 percent more (Lohr, 2001). Organic price premiums are the key in giving organic farming systems comparable or higher whole-farm profits than conventional chemical-intensive systems (Green and Kremen, 2002).

According to the USDA, adoption of organic farming systems showed strong gains between 2002 and 2008 (2010). Organic crops can receive price premiums of anywhere between

10 to 200 percent or more over conventionally grown products. These higher prices can translate to higher profits for organic producers (University of Kentucky/CES, 2007). Potential benefits from organic farming systems include improved soil tilth and productivity, lower energy use, and reduced use of pesticides that can cause acute and chronic illness in humans as well as damage to fish and wildlife (Green and Kremen, 2002).

Under certain circumstances, organic systems may be more profitable than conventional systems, even without price premiums due to higher yields in drier areas or periods, lower input costs, or higher revenue from the mix of crops used in the system (Dimitri and Greene, 2002). Other studies indicated that organic systems can be more profitable than conventional systems even without price premiums due to higher yields in drier areas or periods (Welsh, 1999).

As other studies show, it is profitable to produce organic corn for various reasons. Bertramsen and Dobbs (2001) concluded price premiums for organically produced corn compared to conventionally produced corn forced many producers to change their production practices towards organic farming. And organic corn prices were higher than Unites States cash prices for conventional corn from 1995 to 2000 (Bertramsen and Dobbs, 2001). Heiman and Peterson (2008) determined that according to shipment records of an organic marketing cooperative from 2003 to 2005, organic corn and soybean premiums exceeded 100 percent of the conventional prices, and the organic feed grade corn premium averaged $2.59 per bushel (119.7 percent of conventional prices).

According to Klepper et al. (2001) the clearest difference between organic and conventional producers is in corn grain, for which the conventional group had higher yields. The organic farms produced somewhat less crop output per acre of cropland than their conventional counterparts; however, the variable costs of crop production per acre were higher for conventional groups. This was mainly due to the extra cost of the chemical inputs in conventional production that are not used in organic farming.

1.2.1. Technology Adoption

Though the concept of multifunctional agriculture is very broad, the most of it is the adoption of various agricultural technologies by producers. Different studies show that adoptions of some technologies can positively affect soil properties and harvested yields. For example, furrow disking reduces water consumption and improves yield and net returns (Nuti et al. 2009). Using such innovations led to both production and environmental benefits (Blazy et al. 2009). Producers may be able to reduce risk exposure by trying new techniques on their more marginal lands, typically more steeply sloped, relatively less productive parcels (at least initially) (Arellanes and Lee 2003). Such technology practices adopted by agricultural producers can include irrigation scheduling, water saving, conservation tillage, organic farming, nitrogen fertilization, and plastic-covered horticulture and cover cropping, among others (Bertuglia et al. 2006).

1.2.1.1. Cover Crops

Cover cropping itself can be used for different purposes under different motivating conditions. Cover crops can positively affect soil properties and can improve crop development and yield. Much research has focused on how cover crops affect different attributes of soil and harvested yield. Cover crops can influence soil properties, crop yield and growth (both above and below ground biomass, in tomatoes, for example) (Sainju et al., 2002). They also show that cover crops affect soil carbon sequestration, microbial biomass and microbial activities by providing additional residue carbon to soil (Sainju et al., 2007).

Cover crops can also decrease weed populations in lettuce (Ngouajio et al., 2002), and legume cover crops can provide nitrogen to the next crop and reduce nitrogen requirements

(Larson et al., 2001). Cover crop management has a significant effect on soil penetration resistance in several situations such as how the grazing of cover crops in a grain-cropping system can increase economic return and diversify the agricultural production system while not damage the soil (Franzluebbers and Stuedemann, 2008). Crops following cover crops show the best economic results (Bechini and Castoldi, 2009). No tillage in combination with adapted cover crops and crop rotations result in reducing water runoff and consequently soil erosion, and winter cover crops result in significant yield increase of the following cash crops (Derpsch et al., 1986). Cover-crop mulching offers opportunities for smallholders by increasing soil fertility and improving weed management (Erenstein, 2003).

Another effect of cover crops is decreased nitrogen leaching rates of soil. Sainju et al. (2002) show that hairy vetch and crimson clover, both leguminous cover crops, fix nitrogen from the atmosphere. In another study, Sainju et al. (2007) show that cotton and sorghum yields and nitrogen uptake can be optimized, and potential for soil erosion and nitrogen leaching can be reduced by using conservation tillage, such as no-till or strip-till, in combination with a vetch/rye cover crop and 60-65 kg nitrogen/ha (54-58 lbs/acre). Others show that cover crops reduce soil nitrogen content in autumn and spring (Kramberger et al., 2000). Steenwerth and Belina (2004) describe how cover crops enhanced the soils' capacity for supporting greater microbial biomass nitrogen, potential nitrogen mineralization, and the microbiological function of nitrification and denitrification. Others have demonstrated that nitrate leaching was reduced by 40 percent in legume-based systems relative to a conventional fertilizer-based system (Tonitto et al., 2005).

Though the majority of the articles show that cover crops help reduce nitrogen leaching (field studies conducted in different states and countries), some studies show that sometimes there is no difference statistically in yields between cover crop and non-cover crop treatments (Ritter et al., 1998; Franzluebbers and Stuedemann, 2008).

In organic farming systems, weeds are often recognized as the most serious threat to crop production. An alternative to herbicides is the use of cover crops, which can suppress the growth of weeds by competition for light (Teasdale and Mohler, 2000), soil moisture and nutrients (Barberi, 2002). The growth of weeds could be suppressed by sowing cover crops, and the yield reduction of the main crops was alleviated (Uchino et al., 2007). Uchino et al. (2007) also showed that soil seed banks also became lower by sowing cover crops, implying the importance of proper weed management for long-term weed suppression in an organic farming system.

Kuepper (2003) showed that grass cover crops, such as rye and ryegrass, are especially good as "catch crops" – cover crops grown to absorb soluble nutrients from the soil profile to prevent them from leaching. (All cover crops function as catch crops to a greater or lesser degree.) It is a sound strategy, therefore, to apply manure to growing catch crops or just prior to planting them.

1.3. OBJECTIVES

As previous literature shows, cover crops are essential to organic farming. Cover crop adoption provides beneficial effects, including reduced nitrogen leaching to soil and increased crop yields, benefiting both producers and the environment. To our knowledge, there was no article based on a study showing how much cover-crop adoption decreases the nitrogen use by producers econometrically. Previous literature helped us decide to do a study among organic producers in Midwestern United States. Given that focus, our research has these objectives:

1) Identify the determinants of cover-crop adoption,

2) Estimate the change in the probability of adoption of cover crops due to farm, regional, and operator characteristics,

3) Analyze how nitrogen management rate varies by farm for adopters or non-adopters of this technology, and

4) Estimate the change in intensity of decrease in nitrogen use among adopters and non-adopters of cover crops due to farm, regional, and operator characteristics.

CHAPTER 2: LITERATURE REVIEW

2.1. MULTIFUNCTIONAL AGRICULTURE

Agricultural practices have been changed in recent decades because of environmental concerns, increasing population, changing tastes and preferences of consumers, and safety requirements. According to Boody et al. (2005) and Yrjola and Kola (2004), agriculture can produce many public goods and services or externalities. Van Huylenbroeck and Durand (2003) are making the need for change a core concept in European Union agriculture. They described the need for the change in terms of overproduction, environmental degradation, increasing size of the European Union and changing consumer preferences towards nature and safety.

Abler (2004) also writes about the fact that the term multifunctional agriculture was created in the European Union in the late 1990s. It is considered one of the key issues and concepts in European agriculture by Yrjola and Kola (2004), or a foundation for the European model of agriculture by Batie (2003).

Various authors have defined multifunctional agriculture, which is described as an activity that can have multiple outputs and supply more benefits (Abler, 2004). OECD, the Organization for Economic Co-operation and Development, described multifunctionality as producing multiple goods, products, and services by agricultural businesses. A similar definition was given by Clark (2000) with multifunctionality referring to the multiple positive contributions that agriculture can make to economies, environment, and rural amenities. The other description was that multifunctional agriculture attempts to establish a new balance between commodity support and services that are increasingly valued by the public (Moran et al., 2006).

Batie (2003) writes that in the United States the Northeastern region has shown an increased interest in multifunctional agriculture, suggesting that multifunctional attributes have higher income elasticity. According to Hellerstein et al. (2002), this is because the more populated regions of the country are the most concerned with protecting multifunctional rural amenities. Boody et al. (2005) found that environmental and economic benefits can be gained through changes in agricultural land management without increasing public costs.

Brozova and Dabbert et al. (2004) write that organic farming is one aspect of multifunctional agriculture. Several authors (Dimitri and Greene, 2002, University of Kentucky/CES, 2007, Green and Kremen, 2002) have defined organic farming and the development of the organic farming system in the United States.

While Kuepper et al. (2003) and Greene and Kremen (2002) talked about costs and difficulties of organic farming, Lohr (2001 and Greene and Kremen (2002) talked about potential benefits, including price premiums, that organic producers get from their production. Welsh (1999) concluded that organic farming can be more profitable even without price premiums. Bertramsen and Dobbs (2001) concluded that prices for organically produced corn were higher compared to conventionally produced corn. It was concluded that the price premium for organically produced corn can be as much as 100 percent (Heiman and Peterson, 2008, Klepper et al., 2001).

2.2. COVER CROPS

2.2.1. Technology Adoption and Cover Cropping

As already mentioned, adoption of agricultural technologies is a key component of multifunctional agriculture. Those technologies are not being adopted by all of the producers, or it takes some time while producers adopt technologies. Many authors are trying to determine the factors affecting adoption of different technologies. For example, Bertuglia and Calatrava-Requena (2006) concentrate on factors related to the adoption of good agrarian practices (GAP) by protected vegetable growers in plastic-covered horticulture in southeastern Spain. In the same way, Blazy et al. (2009) make an effort to find what innovations have an effect on the banana farming systems in Guadeloupe.

Nuti et al. (2009) show that current agricultural water issues and the need for reduced input costs in farming operations add importance to making sound irrigation decisions to ensure the efficient use of available resources. Their major results showed that furrow diking improved cotton yield in one of the three years. Furrow diking in their studies periodically reduced water consumption and improved yield and net returns.

Another author, Erenstein (2003), presents the agro-ecological potential of mulching as a different technology, and describes its effects on soil conservation and ecology, crop yield and the environment. He points out how mulching can be a better option than cover crops. The author mentions that cover crop mulching is more time consuming and requires more resources (labor and time) than crop residue mulching. In turn, it gives opportunities for smallholders in (sub)humid areas by addressing soil fertility and weed management constraints. The pure investment nature of cover crop mulching is another major issue. The lag-time also implies that smallholders typically minimize their investment in cover crops.

Similarly, Larson et al. (2001) show that though some winter cover crops can reduce yield risk, the rate of adoption is slow among producers. The major factor influencing unfavorable risk rankings of winter cover crops is the cost of establishing the cover crop in the fall.

2.2.2 Advantages and Disadvantages of Cover Crops

Cover cropping is one of the agricultural technologies that is being adopted for various reasons by producers. Numerous field studies in many countries have been trying to determine how cover crops can be beneficial to both producers and the environment. In Italy, Bechini and

Castoldi (2009) found that cover crops showed, on average, a good economic performance (higher harvest yields).

Similarly, Derpsch et al. (1986) determined that a good soil cover is a very effective means of enhancing water infiltration rates and reducing runoff and erosion losses. Cover crops for soil protection during winter have resulted in significant increases in yield of following cash crops. The highest yield of maize which did not receive any fertilizer nitrogen was obtained following the leguminous cover crops lupin and hairy vetch.

Ngouajio et al. (2003) show that cover crops help to decrease the weed population in lettuce. Their results show that cover crop and management systems affected weed emergence. Results also show that all cover crops reduced weed population and prior summer cover crops can improve both conventional and organic vegetable production systems.

On the contrary, the results of Franzluebbers and Stuedemann (2008) show that the effect of cover crop management systems on soil bulk density when averaged across tillage systems, was not significant at any soil depth. Cover crop management typically did not affect water-stable macro-aggregates.

Ritter et al. (1998) concentrated on the quality of groundwater resources in Chesapeake Bay. The main concern was the nitrogen loadings, specifically nitrogen and phosphorus, which resulted in undesirable changes in the Bay. The authors concluded that winter cover crops are not a good best management practice for reducing nitrogen leaching on sandy soils on the Delmarva Peninsula. Another disadvantage of using winter cover crops as a best management practice was the time constraint: cover crops should be planted by October 1 to get optimum cover crop growth and nitrogen uptake.

Different studies were conducted to determine how cover cropping positively affects nitrogen in the soil. All of these analyses have been conducted in the field. The authors attempted to determine advantages of cover crops using field studies. According to Kramberger et al. (2009), cover cropping was one of the solutions to decreasing nitrogen leaching and preserving nitrogen in the soil. The results showed that cover crops significantly affected soil nitrogen content before winter and at maize seeding in the spring. As expected, higher yields of maize were obtained following legumes as cover crops. The results also supported the thesis that nitrogen accumulated by cover crop is only partially recovered by the succeeding crop, the majority of nitrogen stays in the soil and is mineralized later.

In different years, Sainju conducted several studies to identify the benefits of cover crops. Analysis of Sainju et al. (2001) showed that legume cover crops increased soil inorganic nitrogen, organic nitrogen, and organic carbon as well as tomato fruit yield, and biomass. Sainju et al. (2002) showed that cover crops provided greater concentrations of nitrogen and that cover crops fix nitrogen from the atmosphere. Sainju et al. (2007) showed that benefits of cover crops in increasing carbon sequestration and improving soil quality can be achieved more readily in irrigated than in dryland cotton. The other study showed that tillage, cover crops, and nitrogen fertilization rates influenced soil nitrogen availability and cotton and sorghum yields and nitrogen uptake due to variation in the amount of nitrogen returned to the soil by cover crop, cotton and sorghum residues (Sainju et al., 2006).

Steenwerth and Belina (2008) further showed that following cover crops, soils supported greater potential denitrification, nitrification and mineralization than cultivated soils, indicating that cover crop soils have a higher enzymatic capacity for these processes than cultivated soils. Greater microbial biomass nitrogen in cover crop soils indicates that cover crop biomass provided a larger sink for soil nitrogen than existed in cultivated soils.

Tonito et al. (2006) calculated that, on average, nitrate leaching was reduced by 40 percent in legume-based systems relative to conventional fertilizer-based systems. That result shows the importance of using nitrogen- and non-nitrogen -fixing cover crops for diversified rotations.

Teasdale and Mohler (2000) concluded that cover crops can be very useful to control weed population in crop production in organic farming systems. Uchino et al. (2009) showed that soil seed bank can be lowered by sowing cover crops. Barberi (2002) determined that cover crops fix soil moisture and nutrients for organic production. Kuepper (2003) concluded that grass cover crops were good for “cash” crops (corn).

CHAPTER 3: DATA AND METHODOLOGY

3.1 DATA

3.1.1 Survey Design

This analysis was based on the survey results administered by The Survey Research Institute at Cornell University (SRI), which was contracted by a group of universities and non-profit organizations (Cornell University College of Agriculture, Michigan State University, University of California Davis, University of Illinois at Urbana Champaign, World Resources Institute, Louisiana State University Agricultural Center) working with the National Science Foundation to administer and process a mail questionnaire of corn producers in the Mississippi River Basin.

The SRI designed a scan-able questionnaire, coordinated material preparations, and mailed survey packets. Each packet contained an introductory letter, a questionnaire, and a postage-paid reply envelope directed to the University of Illinois at Urbana Champaign (UIUC). Questionnaires were received and inventoried at UIUC and then passed to SRI for scanning and processing. SRI sent three follow-up mailings for non-respondents (see mailing timeline below).

All producers in the sample were believed to operate in the Mississippi River Basin. The survey was sent to organic and conventional producers. Originally the survey was sent to 2,068 conventional and 932 organic producers. 233 organic and 213 conventional producers completed questionnaires, giving 25% and 10.3% response rates respectively. Project statistics, mailing timeline, and processed surveys by sample type are presented in Appendix B.

The questionnaire was 12 pages long, which included a cover page with the title. Producers were asked a variety of questions including cover crop adoption, demographic, and general farm information. The survey was designed using Dillman's (2000) tailored design method, including a pre-notice letter to producers, questionnaire mailing, reminder postcards, and a replacement questionnaire (see Appendix A for the copy of the questionnaire).

We compared summary statistics using 2007 census data of survey respondents to the sample population provides support for the representativeness of the data set collected. These summary statistics are provided in Table 1 (USDA-NASS-2007).

The final results of our analysis are based on 233 observations of completed surveys from organic producers. Completed observations were collected from 7 states (Illinois, Indiana, Iowa, Ohio, Michigan, Minnesota, and Wisconsin). Table 3.2 shows the distribution of observations by those states.

3.1.2. Dependent Variables

The dependent variable in the probit model (the cover crop adoption) is a discrete choice variable we determined from the survey asking the producer's response to whether they currently used cover crops in their farming operation. If producers answered "yes" then they were asked what type of cover crops they used and how long they had used cover crops. The mean value of 0.54 shows that 54 % of the producers adopted cover crops (table 3.2). The table also shows the distribution of organic producers in those states based on 2008 agricultural census data by USDA-NASS (USDA-NASS-2008).

The dependent variable in the Tobit model was nitrogen use by the producer in pounds per acre. Nitrogen use is a continuous variable, which shows how much nitrogen producers are using per acre of cropland (corn). The data show that the mean level of nitrogen applied per acre was 53.4 pounds per year (table 3.3). Nitrogen use was justified by calculating the amount of nitrogen content of different fertilizers containing nitrogen and different animal manure that a producer applied to his corn field. Different conversion ratios were used for the calculations depending on the type of fertilizer and the type of manure (See Appendix C for the calculations of nitrogen content used by producers).

Table 3.1 – Comparing Summary Statistics for Survey Respondents and 2007 Agricultural Census Data

Categories	Distribution	
	Percent of total (Survey data)	Percent of total (USDA data)
Farms by size:		
1-9 acres	1	10
10-49	3	28
50-179	8	30
180-499	38	17
500-999	24	7
1000-1999	19	4
2000 and more	7	4
Farms by type of organization:		
Family or individual	88	87
Partnership	2	8
Corporation	7	4
Other	3	1
By economic class:		
Less than $1,000	6	23
$1,000 to $2,499	1	12
$2,500 to $4,999	1	11
$5,000 to $9,999	1	12
$10,000 to $24,999	6	12
$25,000 to $49,999	7	7
$50,000 to $99,999	18	6
$100,000 to $249,999	40	7
$250,000 to $499,999	13	4
$500,000 to $999,999	7	3
$1,000,000 or more	6	3

Table 3.2 - Distribution of the Observations by State

State	Number of observations	Percent of total (Survey data)	Percent of total (USDA data)
Illinois	36	15.45	6
Indiana	3	1.29	4
Iowa	56	24.03	14
Ohio	15	6.44	15
Michigan	13	5.58	13
Minnesota	48	20.60	15
Wisconsin	62	26.61	33

Table 3.3 – Definitions and Summary Statistics of the Dependent Variables Used in the Analysis

Variable	Description	Mean	Predicted sing
Cover crop	Equals to '1' if cover crop used in the corn field, '0' otherwise.	0.538835	N/A
Nitrogen	Amount of nitrogen use on corn field (pounds per acre in 2008)	53.3964	N/A

3.1.3. Explanatory Variables

The explanatory variables can be divided into three categories: demographic, socio-economic, and farm-related. Demographic variables included age, region, off farm work, education, and farming experience. Socio-economic variables included total farm income (in $100,000), rented field, share rented, livestock, other producers (who grow cover crops), organic fertilizer dealers, and organizations, promoting cover crops and legumes as information sources when making nitrogen management decisions. Farm-related variables included predicted values of cover crops, farm size, conservation payments, slope 6%, slope 12%, and tile drainage.

3.1.3.1. Demographic Variables

Table 3.4 contains definitions and summary statistics of demographic variables used in the probit and tobit models. We didn't know what effect region would have on cover crop adoption, and we wanted to see whether there was any significant difference in adoption of cover crops by state or place due to different farming practices used in different regions (e.g. cattle breeding instead of plant growing). The observations were not equally distributed by states, so we further grouped the seven states into two regions: Corn Belt states (Illinois, Indiana, Iowa, and Ohio) and Lake States (Michigan, Minnesota, and Wisconsin).

Table 3.4 – Definitions and Summary Statistics of the Demographic Variables

Variable	**Description**	**Mean**	**Predicted sign**
Age	Producer's age in years	52.93396	-
Region	Equals: '1' if the farm is in Corn Belt, '0' if in Lake States region	0.472103	?
Off farm work	Equals: '0' if the producer didn't work off farm during 2008; '1' if the producer worked 1-49 days off farm; '2' if 50-99 days; '3' if 100-199 days; and '4' more than 200 days	1.02765	-
Education	Producer's highest level of education. Equals: '1' if the producer has less than high school; '2' if high school or equivalent (such as GED); '3' if some collage or equivalent training; '4' if college bachelor degree; and '5' if advance degree.	2.770642	+/- *
Experience	Number of years of farming in years.	29.92453	+

* - the predicted sign is positive for cover crop adoption and negative for nitrogen use by producers

We wanted to use ERS regions (Northern Crescent and Hearlend), however, those regions were not formed by complete state borders. So we couldn't use those ERS regions in our analysis. Region was a dummy variable that took the value of '1' if the farm was in the Corn Belt region, '0' if in the Lake States. The mean value of 0.54 showed that 54% of producers were located in Corn Belt region and 46% were located in the Lake States.

Producer's age was a continuous variable showing surveyed producers' age, with 47 years as a mean age. We assumed that producer's age would have a negative impact on cover crop adoption due to the lack of the trust towards new technologies. However, different studies detected different relationship between the age and the cover crop adoption. Arellanes and Lee (2003) determined that age had negative impact on cover crop adoption, while Neill and Lee (1999) determined that age had positive impact on cover crop adoption.

Off-farm work was a categorical variable which showed the number of days a producer worked off the farm for pay for at least four hours per day during 2008. This variable equals to '0' if the producer did not work off the farm, '1' if the producer worked 1-49 days off farm, '2' if 50-99 days, '3' if 100-199 days, and '4' if more than 200 days off the farm for at least four hours per day during 2008. The mean number is 1.02, which shows that, on average, producers worked 1-49 days off farm during 2008.

Off farm work was expected to have a negative impact on cover crop adoption, particularly due to the scarcity of time for farming in the own farm. In our analysis off-farm work was a categorical variable. Neill and Lee (1999) found supporting result to this assumption. They concluded that there is negative relationship between off farm income and cover crop adoption though they had used off farm income as a variable. But we assumed that if the producer worked more off farm than he would have more off farm income as well.

Education was a categorical variable showing the highest level of education a producer attained. This variable equals '1' if the producer has less than high school; '2' if high school or equivalent (such as GED); '3' if some collage or equivalent training; '4' if college bachelor degree; and '5' if advance degree. The value of 2.7 showed that half of the surveyed producers completed more than high school or equivalent education.

We hypothesized that education would have positive impact on adoption of cover crops due to more knowledge about agricultural innovations, benefits of cover crops, and its impact on the surrounding environment. Similar result had Gerard et al. (1993), when they determined that education had adoption of sustainable agricultural model.

Experience was a continuous variable showing the number of years of farming. Producers had 30 years of experience, on average, in the group. It was expected that producers with more farming experience would have more initiatives to adopt cover crops because of the previous benefits received from the use of cover crops. However, previous literature partially supported our expectation. Experience had positive impact on adoption of cover crops in Arellanes and Lee's (2003) study, while it had negative impact on perceived benefits of cover crop adoption in another study (Bergtold et al., 2008).

3.1.3.2. Socio-Economic Variables

Table 3.5 contains definitions and summary statistics of socio-economic variables used in the probit and tobit models.

Total farm income (in $100,000/year) was a continuous variable, which showed the total farm income in 2008. The mean of 3.21 indicates that the mean farm income was $321,000 in 2008. Though Bergtold et al. (2008) had farm sales in their study; they concluded that farm sales had positive impact on adoption. Presuming that farm sales and farm income are correlated to each other we expected to have the same relationship between farm income and cover crop adoption in our analysis. This is basically due to the expectation that incorporating cover crops gives higher return.

Rented field showed if a producer was renting the highest yielding corn field. It was

Table 3.5 – Definitions and Summary Statistics of the Socio-Economic Variables

Variable	Description	Mean	Predicted sign
Farm income	Total farm income (in $100,000/year).	3.213944	+/?
Proportion of rented field	Proportion of cropland rented.	0.516654	-
Rented field	Equals: '1' if the highest corn field is rented, '0' otherwise.	0.381974	-
Livestock	Equals: '1' if the farm has the livestock, '0' otherwise.	0.673819	+
ISDS_COV	Equals: '1' if importance of producers (who grow cover crops) on nitrogen decision making is low; '2' if moderate;'3'if high; and '4' if very high.	4.036649	+
ISDS_ODE	Equals: '1' if importance of organic fertilizer dealers on nitrogen decision making is low; '2' if moderate; '3'if high; and '4' if very high.	2.86631	?
ISDS_ORG	Equals: '1' if importance of organizations, promoting cover crops and legumes on nitrogen decision making is low; '2' if moderate; '3'if high; and '4' if very high.	2.94362	+

* - the predicted sign is positive for cover crop adoption and negative for nitrogen use by producers

dummy variable that showed whether the highest yielding corn field was rented or not in 2008,and was equal to '1' if the highest yielding corn field was rented, '0' otherwise. And survey results show that 38% of producers rented this field in 2008. We assumed that this variable would have negative impact on nitrogen use due to more cost associated with renting the field. As producers pay more money to rent the field they have less money to incorporate required amount of nitrogen.

Proportion of rented field was a continuous variable which showed the proportion of the cropland that was rented. The mean of 0.52 shows that 52 % of all the cropland was rented. We expected that if the proportion of rented field increased then the adoption would decrease.

Arellanes and Lee (2003) determined that owing the farm had positive impact on adoption of cover crops. It was assumed that if the field ownership had positive impact on adoption then or renting the field would have negative impact. We expected this negative relationship again due to increased cost of overall farming.

Livestock was a dummy variable describing the existence of livestock on the farm. It was equal to '1' if the farm had livestock, '0' otherwise. Survey showed that there is, at least, some kind of livestock on 67% of the farms. We predicted the sign of coefficient of livestock to be positively related to nitrogen use. The positive relationship was assumed due the assumption that if the producer had any kind of livestock in the farm then there was high probability that he would use the manure as a fertilizer. And as we included the nitrogen content of the manure used in the farm, it means that existence of livestock would increase the nitrogen use.

Other producers (who grow cover crops manure or legumes) (ISDS_COV) as a source of information when making nitrogen management decisions was a categorical variable equal to '1' if the importance of producers relying on cover crops in decision making is low; '2' if moderate;'3'if high; and '4' if very high. The data showed that the level of importance of producers relying on commercial N was high for the producers. We hypothesized that if the level of importance of other producers (who grow cover crops) as an information source for nitrogen management decision making is higher than the nitrogen use would increase as well. This positive relationship was assumed due to the fact that producers trust each other and often adopt the same technology as their neighbor producers.

Organic fertilizer dealers (ISDS_ODE) as a source of information when making nitrogen management decisions was a categorical variable equal to '1' if importance of organic fertilizer dealers on decision making is low; '2' if moderate; '3'if high; and '4' if very high. The data showed that the level of importance of producers relying on organic fertilizer dealers was more than moderate for the producers. We didn't know what the expected sign of this variable would be. From one side the relationship could be positive if organic fertilizer dealers promoted cover crops. From the other side the relationship could be negative due to the fear that by promoting cover crops organic fertilizer dealers would decrease their sales.

Organizations promoting cover crops and legumes (ISDS_ORG) as a source of information when making nitrogen management decisions was a categorical variable equal to '1' if the importance of organizations, promoting cover crops and legumes on decision making is low; '2' if moderate; '3'if high; and '4' if very high. The data showed that the level of importance of producers relying on organizations promoting cover crops and legumes was more than a moderate close to high for the producers. We expected the relationship between this variable and cover crop adoption to be positive due to positive information that organizations promoting cover crops gave to consumers.

3.1.3.3. Farm Related Variables

Table 3.6 contain definitions and summary statistics of farm related variables used in the probit and tobit models Cover crop was predicted values of cover crop adoption from the probit model. This variable was supposed to have negative impact on nitrogen use. Different field studies showed that the use of cover crops decreases the nitrogen use (Tonito et al. 2006, Sainju et al. 2001, Sainju et al. 2002, Kramberger et al. 2009). So we assumed that our analysis would be in accordance with the previous studies though they did field studies.

Farm size was a continuous variable showing the number of total acres of the land producer managed. The mean value showed that producers managed almost 934 acres of farmland. We expected this variable to have negative impact on cover crop adoption. This is

Table 3.6 – Definitions and Summary Statistics of the Farm Related Variables

Variable	Description	Mean	Predicted sign
Farm size	Total acres of land on the farm.	933.9644	-/
Cover crop	Predicted values of cover crop adoption from probit model	0.521035	-
Conservation payments	Equals to '1' if the producer got conservation payment, '0' otherwise	0.227467	+/-
Tile drainage	Equals '1' if the farm has artificial drainage, '0' otherwise.	0.360515	?
Slope 6%	Equals '1' if the field has more than 6% slope, '0' otherwise	0.296137	+
Slope 12%	Equals '1' if the field has more than 12% slope, '0' otherwise	0.021459	-

* - the predicted sign is positive for cover crop adoption and negative for nitrogen use by producers

mostly because of the cost that related to cover crops. With bigger farm size there should be more difficulties associated with production and labor management. In their study Bergtold et al. (2008) determined that it had had negative impact on adoption of cover crops. However, Neill and Lee (1999) concluded that farm size had positive impact on adoption of cover crops.

Conservation payment (CRP, WRP, EQIP, CSP, etc.) was a dummy variable, equal to '1' if the producer received any kind of conservation payment, '0' otherwise. Our date showed that only 23% of producers had received conservation payments. We assumed that there should be positive relationship between conservation payments and cover crop adoption as a result of extra payments producers receive. Cover cropping is associated with extra cost (Larson et al. 2001), so the producers are more likely to adopt cover crops if they receive extra money. We also wanted to see whether conservation payments had any significant effect on nitrogen use. We didn't know what relationship there would be between conservation payments and nitrogen use.

Slope 6% was a dummy variable, equal to '1' if the field had more than 6% slope, '0' otherwise. 30 % of the fields had more than a 6% slope. Soil erosion is happening with greater rates if the field has higher slope. We also know that cover crops efficiently reduce water runoff and thus soil erosion (Derpsch et al., 1986; Ritter et al., 1989). So having this background we expected the coefficient for this variable to be positively related to cover crop adoption. Neill and Lee (1999) determined that that the slope had positive impact on adoption of cover crops.

Slope 12% was a dummy variable, equal to '1' if the field had more than 12% slope, '0' otherwise. Only 2 % of the fields had more than 12% slope. The coefficient sign of this variable was expected to be positively related to nitrogen use by producers due to the increased amount of nitrogen leakage in higher sloped fields.

Tile drainage was a dummy variable, equal to '1' if the field had subsurface (tile) drainage, '0' otherwise. And the data showed that, on average, 36% of the farms had artificial drainage. Gast et al. (1978) determined that there was nitrogen loss in tile drainage systems. So if there was a negative impact on nitrogen content in tile drainage, so we expected that there would be positive relationship between higher slope and nitrogen use due to nitrogen loss associated with tile drainage.

3.2. METHODOLOGY

3.2.1. Emperical Model

The first stage of analysis was the probit model, analyzing factors that have an effect on cover crop adoption.

3.2.1.1. Probit Model

Hill et al. (2008) showed us that we can examine the effect of a one unit change in independent variable on the probability that dependent variable equals to one (that producer adopts cover crop) by considering the derivative of the probit model. Greene (2000) mentioned that logistical distribution is similar to the normal except the tails; therefore, two tend to give the similar probabilities. Similarly Amemiya (1981) noted that only at the tails of probit and logit distributions are noticeably different but the difference is not much.

Looking on the frequency distribution of two continues variables (age and years of experience) below we could see that age is normally distributed while years of experience had longer tail on the right side (Figure 3.1 and 3.2).

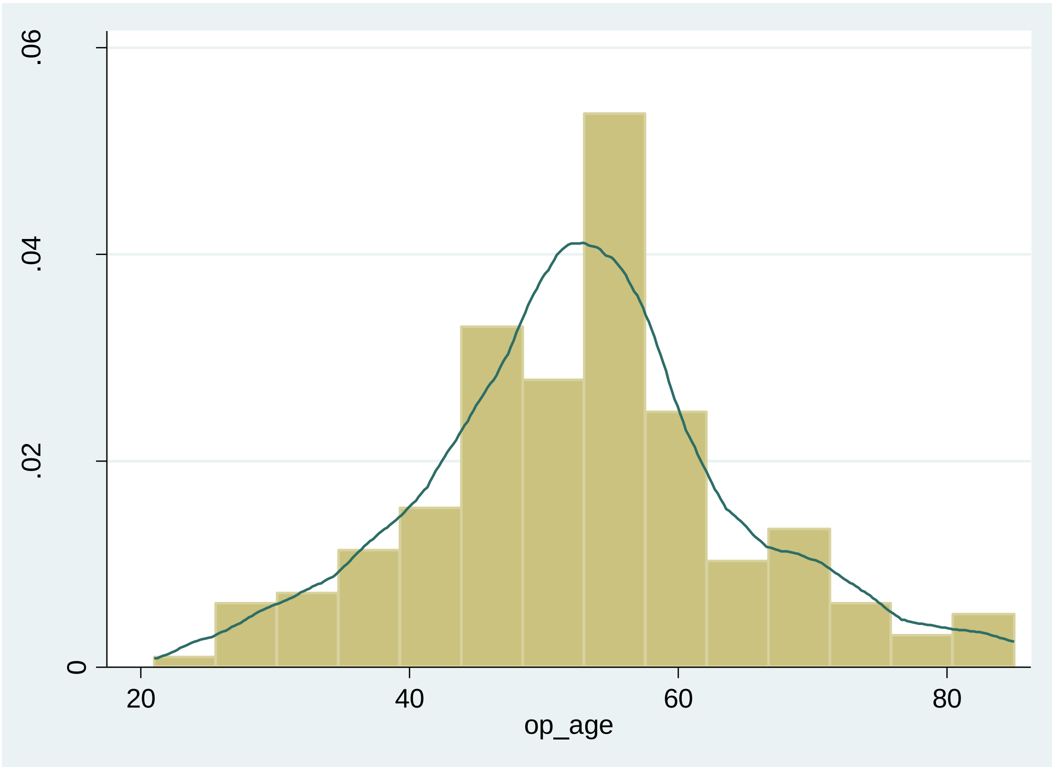

Figure 3.1 – Frequency distribution of age

Having this background, we decided to use probit model for first stage of our analysis.

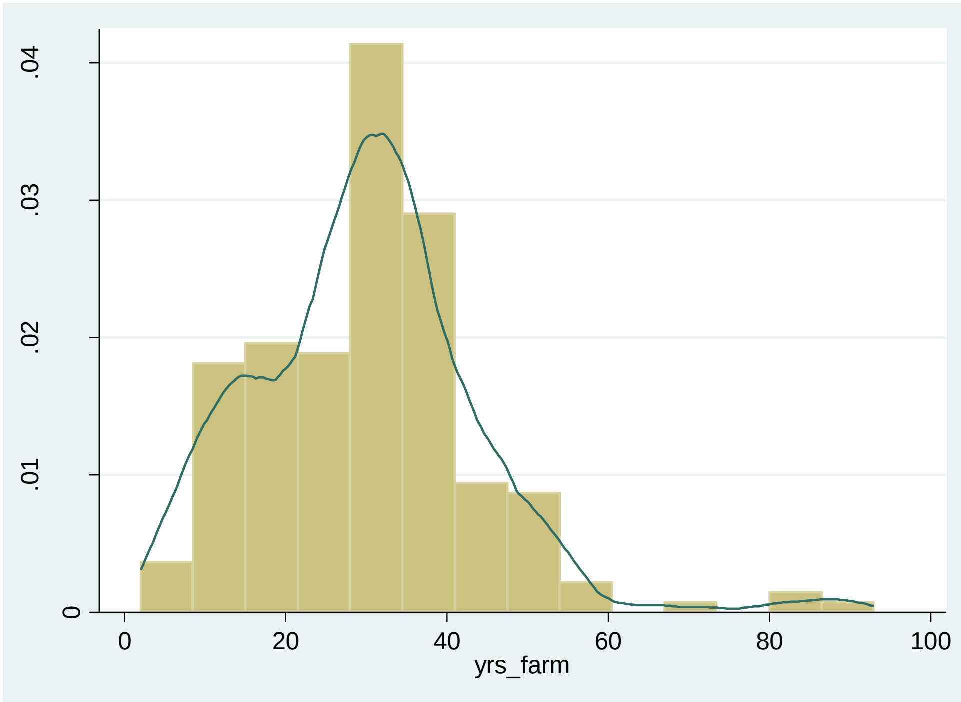

Figure 3.1 – Frequency Distribution of Years of Experience.

Considering Y_1 is a dummy variable, we estimate it using a Probit model to understand the probability of adoption such that

1) $$Y_1 \begin{cases} 1 = W'\beta + v_i = Y_1^* \\ 0 \end{cases}$$

Where, Y_1 is a latent variable that is continuously observed, W' is an exogenous variable vector, and β is a parameter estimates vector. The errors of Probit and Tobit model follow the distribution

2) $$(v_i, u_i) \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \rho\sigma_u \\ \rho\sigma_v & 1 \end{pmatrix}\right]$$

The Probit statistical model expresses the probability that Y_2 takes the value of 1 to be

3) $$p = P[Z \leq W'\beta + v_i] = \Phi(W'\beta + v_i)$$

3.2.1.1.1. Marginal Effects

Hill et al (2008) shows us that we can examine the effect of a 1 unit change in W' on the probability that Y_1 =1 by considering the derivative

4) $$\frac{dp}{dx} = \frac{d\Phi(t)}{dt} \cdot \frac{dt}{dx} = \Phi(W'\beta + v_i)\beta$$

Where t = $W'\beta + v_i$ and $\Phi(W'\beta + v_i)$ is a standard normal probability density function evaluated at $W'\beta + v_i$. To get the result, we can use chain rule of differentiation. This result gives us the marginal effect of dependent variables on cover crop adoption.

Greene (2008) shows in more details how to calculate marginal effect for the probit model. He suggests calculating standard errors, using the linear approximation approach.

For predicted probabilities,

5) $$Asy.Var\left[\hat{F}\right] = \left[\frac{\partial \hat{F}}{\partial \hat{\beta}}\right]' \boldsymbol{V} \left[\frac{\partial \hat{F}}{\partial \hat{\beta}}\right]$$

where

6) $$V = Asy.Var[\hat{\beta}]$$

As described earlier, there can be three different asymptotic covariance matrices of $\hat{\beta}$, let $z = \boldsymbol{x}'\hat{\boldsymbol{\beta}}$. Then the derivative vector is given by the following equation

7) $$\left[\frac{\partial \hat{F}}{\partial \hat{\beta}}\right]' = \left[\frac{d\hat{F}}{dz}\right]' \left[\frac{\partial z}{\partial \hat{\beta}}\right] = \hat{f}x$$

After combining the terms we get

8) $$Asy.Var\left[\hat{F}s\right] = \hat{f}^2 \boldsymbol{x}'\boldsymbol{V}\boldsymbol{x}$$

which depends on the particular x variable used. This result is useful when the marginal effect is counted for a dummy variable. In this case, the estimated effect is

9) $$\Delta\hat{F} = \hat{F}|(d=1) - \hat{F}|(d=0)$$

The asymptotic variance would be

10) $$Asy.Var\left[\Delta\hat{F}\right] = \left[\frac{\partial \Delta\hat{F}}{\partial \hat{\beta}}\right]' \boldsymbol{V} \left[\frac{\partial \Delta\hat{F}}{\partial \hat{\beta}}\right]$$

where

11) $$\left[\frac{\partial \Delta \hat{F}}{\partial \hat{\beta}}\right] = \hat{f}_1 \begin{pmatrix} \bar{x}_{(d)} \\ 1 \end{pmatrix} - \hat{f}_0 \begin{pmatrix} \bar{x}_{(d)} \\ 0 \end{pmatrix}$$

The matrix of marginal effects is

12) $$\hat{f}\left(\frac{\partial \hat{\beta}}{\partial \hat{\beta}'}\right) + \hat{\beta}\left(\frac{d\hat{f}}{dz}\right)\left(\frac{\partial z}{\partial \hat{\beta}'}\right) = \hat{f}I + \left(\frac{d\hat{f}}{dz}\right)\hat{\beta}x'$$

For probit model

13) $$\frac{df}{dz} = -z\phi$$

so $Asy.Var[\hat{\gamma}] = \phi^2[I - (x'\beta)\beta x']V[I - (x'\beta)\beta x']'$

3.2.1.2. Censored Data

Nitrogen use by producers is considered as censored data, because a substantial fraction of the observations on the dependent variable take a limit value, which can be equal to zero.

When the dependent variable is censored, we cannot use the least squares method to obtain regression parameters because the parameters obtained by least squares are biased and inconsistent if the data are censored. Our dependent variable is a variable with quantitative meaning, *y**, and we are interested in the population regression *E(y*)*. If *y** were observed for the population we could use least squares. But the data problem arises in that y^* is censored from below, when some part of the population does not use nitrogen (nitrogen use equals 0).

When a distribution is censored on the left, observations with values at or below τ are set to τ_y.

14) $$y = \begin{cases} y^* & if \quad y^* > \tau \\ \tau_y & if \quad y^* \leq \tau \end{cases}$$

The use of τ and τ_y are just a generalization of having τ and τ_y set at 0. If a continuous variable y has a pdf *f(y)* and τ is constant, then we have

15) $$f(y) = [f(y^*)]^{d_i}\,[F(\tau)]^{1-d_i}$$

So we see that the density function of y is the same as that for y^* for $y > \tau$, and is equal to the probability of observing $y^* < \tau$ if $y^* = \tau$. d is an indicator variable that equals 1 if $y^* > \tau$, so the observation is uncensored and is equal to 0 if $y = \tau$, so the observation is biased.

The probability of the censored distribution would be,

16) $$P(censored) = P(y^* \leq \tau) = \Phi\left(\frac{\tau - \mu}{\sigma}\right) = 1 - \Phi\left(\frac{\mu - \tau}{\sigma}\right)$$

and

17) $$P(uncensored) = 1 - \Phi\left(\frac{\tau - \mu}{\sigma}\right) = \Phi\left(\frac{\mu - \tau}{\sigma}\right)$$

Thus, the likelihood function can be written as

18) $$L = \prod_i^N \left[\frac{1}{\sigma}\phi\left(\frac{y - \mu}{\sigma}\right)\right]^{d_i}\left[1 - \Phi\left(\frac{\mu - \tau}{\sigma}\right)\right]^{1 - d_i}$$

3.2.1.3. Tobit Model

So as we see, we cannot use OLS for our censored data, but we can use the Tobit model. This model recognizes that we have two types of data, the limit observations (y = 0) and non-linear observation (y > 0) (Hill at al. 2008).

Greene gives us the structural equation of the Tobit model which is:

19) $$y_i^* = X_i\beta + u_i$$

where $\varepsilon_i \sim N(o, \sigma^2)$. y^* is a latent variable that is observed for values greater than τт and censored otherwise. The observed defined by following measurement equation

20) $$y = \begin{cases} y^* & if \quad y^* > \tau \\ \tau_y & if \quad y^* \leq \tau \end{cases}$$

In the typical Tobit model, we assume that τт = 0, i.e. the data are censored at 0. Thus, we have

21) $$y = \begin{cases} y^* & if \quad y^* > 0 \\ 0 & if \quad y^* \leq 0 \end{cases}$$

While nitrogen use by producers is considered as a left censored variable, adoption of cover crops is considered as an endogenous dummy variable. The resulting system is a LDV model defined by the amount of nitrogen use by producers, with an endogenous dummy variable that investigates whether the producer adopts cover crops. Because the censoring precludes unique or sensible solutions for the reduced forms, a condition must be imposed in a system of censored dependent variables (Heckman, 2001). The structural form of the model is given by

22) $$Y_2^* = X'\beta + {Y_2}'\gamma + u_i$$

We assume that Y_2^* = Y_2^* is continuously observed such that

23) $$\begin{cases} Y_2^* = X'\beta + {Y_2}'\gamma + u_i & if\ Y_2 > 0 \\ Y_2^* = 0 & if\ Y_2 \leq 0 \end{cases}$$

where Y_2 represents the amount of nitrogen use by producers per acre and is censored at zero. X' is a vector of independent exogenous variables, β is a vector of parameter estimates, and Y_2 represents the probability of adopting cover crops. The amount of nitrogen use is dependent on exogenous variables X and a dummy variable Y_2 representing the probability of adopting a cover crop, which is potentially endogenous.

We already showed the likelihood function for the censored normal distribution (equation 8), where τ is the censoring point. In the traditional Tobit model, τ is set to zero, $\tau = 0$, and substitute μ for $X_i\beta$. This gives us the likelihood function for the Tobit model.

24) $$L = \prod_i^N \left[\frac{1}{\sigma}\phi\left(\frac{y_i - \mathrm{X_i}\beta}{\sigma}\right)\right]^{d_i}\left[1 - \Phi\left(\frac{\mathrm{X_i}\beta}{\sigma}\right)\right]^{1-d_i}$$

The log likelihood function for the Tobit model is

25) $$lnL = \sum_{i=1}^N \left\{d_i\left(-ln\sigma + ln\phi\left(\frac{y_i - \mathrm{X_i}\beta}{\sigma}\right)\right)(1 - d_i)\ln\left(1 - \phi\left(\frac{\mathrm{X_i}\beta}{\sigma}\right)\right)\right\}$$

The overall log-likelihood is made up of two parts. The first corresponds to the classical regression for the uncensored observations, while the second part corresponds to the relevant probabilities that an observation is censored.

3.2.1.3.1. Marginal Effects

There are potentially three conditional mean fractions to consider, depending on the purpose of the study (Greene). As there are three expected values, there are three marginal effects as well; marginal effect on the latent dependent variable, $y*$, marginal effect on the expected value for *y* for uncensored observations, and marginal effect on the expected value for *y* (censored and uncensored). We can calculate the marginal effect on the latent dependent variable y^* by the following equation;

26) $$\frac{\delta E[y^*]}{\delta x_k} = \beta_k$$

Greene (2000) suggests that McDonald and Moffitt's (1980) decomposition is very useful tool for calculating marginal effects for Tobit model. Marginal effect on the expected value for y (censored and uncensored observations);

27) $$\frac{\partial E[y]}{\partial x_k} = \phi\left(\frac{X_i\beta}{\sigma}\right)\beta_k$$

which can be rewritten as the following,

28) $$\frac{\partial E[y]}{\partial x_k} = P(y > 0)\frac{\partial E[y|y > 0]}{\partial x_k} +)\partial E[y|y > 0])\frac{\partial P(y > 0)}{\partial x_k}$$

Thus, the reported Tobit coefficients indicate how a one unit change in an independent variable x_k alters the latent variable.

3.2.1.4. Endogeneity

As we already mentioned above, the structural form of the tobit model is given by

29) $$Y_2^* = X'\beta + Y_1{}'\gamma + u_i$$

The amount of nitrogen use is dependent on exogenous variables X and a dummy variable Y_2 representing the probability of adopting a cover crop, which is potentially endogenous. Probability of adoption of cover crops is dependent on Z variables which are uncorrelated with u_i. Endogeneity tests of acres of GM corn planted and hours worked off the farm are considered. We use the Smith Blundell test to determine exogeneity as proposed by Baum (1999), who computes a test for exogeneity based on the Smith and Blundell's test (1989) where, under the null hypothesis, the models are appropriately specified with all explanatory variables as exogenous. Under the alternative hypothesis, the suspected endogenous variables are expressed as linear projections of a set of instruments, and the residuals from the first stage regressions are added to the model.

Considerable literature has evolved in the use of limited dependent variable model with endogenous dummy variable. Amemiya (1974) considers a model in which all endogenous variables are truncated to zero, revealing certain necessary restrictions on the model and suggesting a method of estimation using the indirect least squares method. Nelson and Olson (1978) proposed a two-stage least squares procedure for Tobit analysis proving that the estimates are asymptotically normal. More recent studies have applied these models for specifying effects on adoption of technologies including Blundell and Smith (1989) who compared estimates of marginal and marginal and new conditional maximum likelihood procedures. Goodwin and Mishra (2004) used the simultaneous equation framework to determine multiple job holdings and resulting effects on farming efficiency. A more detailed discussion on use of LDV with dummy endogenous model is presented by Angrist, J.D. (2001).

CHAPTER 4: RESULTS

4.1 FIRST STAGE – PROBIT MODEL

Our finding represents the results of organic producers in Midwestern U.S. region.

Table 4.1 summarizes the results from the probit model used to determine which factors affect cover crop adoption by producers. These variables were included in the model based on their importance for cover crop adoption. Overall model significance was checked by using the chi square test. The model was significant at the 1% level, and had 127 observations.

Operators' age was significant (5% level) and positive (0.038486). This means that older operators are more likely to adopt cover crops than younger producers. The marginal effect was 0.015, which suggests that if the organic producer in the Midwestern United States is one year older, then the probability of adopting cover crops increases by 0.015. This result was not accordance with our expectations.

The other significant demographic variable was farming experience. The variable was significant (5% level) and negative (-0.1314) with marginal effect equal to -0.052. This shows that there is negative relationship between cover crop adoption and farming experience.

Experience squared was also significant (5% level) and had positive (0.00226) relationship with cover crop adoption. The signs of coefficients of experience and experience squared showed us that there was U-shaped relationship between adoption of cover crops and experience. This means that the slope of farming experience changes its sign. Taking a derivative of the model with the respect to farming experience, we calculated that the turning point is 50 years.

Farm size had positive (0.00037) and significant (5% level) effect on adoption of cover crops as well, which was not in accordance with our predictions it was not significant. This result

Table 4.1 – Results of First Stage, Probit Model

Cover_crop	Coefficient	Standard Error	Marginal Effect
Age**	0.038486	0.01888	0.015301
Farm size**	0.000367	0.000148	0.000146
Farm income**	-0.12938	0.053405	-0.05144
Education	-0.07002	0.136631	-0.02784
Experience**	-0.1314	0.053542	-0.05224
Expsq**	0.00226	0.001036	0.000899
Proportion of rented field	-0.11276	0.114789	-0.04483
Region (Northern Crescent)	-0.42167	0.267113	-0.16671
ISDS_COV*	0.232812	0.131134	0.092562
ISDS_ORG	0.114494	0.116085	0.045521
ISDS_ODE*	-0.21059	0.115494	-0.08373
Conservation payments*	0.54105	0.328359	0.209468
Slope (>6%)	-0.41399	0.355918	-0.1637
Intercept/constant	-0.66191	1.19023	

* - 10% significance, ** - 5% significance

illustrates that if the farm size increases in size, producers have more initiatives to adopt cover crops. The marginal effect shows that if farm size increases by 100 acres the probability of adoption increases by 1.5%. This shows that if producers have bigger farm they have incentives to adopt cover crops. This result was relevant to the result determined by Neill and Lees (1999).

Total farm income, a socio-economic variable, was significant (at 5% level). The coefficient was negative (-0.12938), indicating there is negative relationship between cover crop adoption and total farm income. A way to interpret the marginal effect is that when total farm income increases by $100,000, the probability of cover crop adoption decreases by a probability of 0.0514. This negative relationship implies that as producers' income increases they are less likely to adopt cover crops. This relationship is opposite what we initially expected; if the producer has more income, he will have more incentives and financial resources to adopt cover crops.

Relying on other producers for cover crop information when making N management decisions was another significant (10% level) socio-economic variable and was positive (0.232812). If the level of importance of other producers who rely on cover crops increases as an information source then probability of adopting cover crop increases by 0.0926. This positive relationship is reasonable, because producers frequently use other producers and their experience to help make decisions about farming practices. And this relationship is consistent with our predictions.

Organic fertilizer dealers as an information source was significant (10% level) and negative (-0.21059). This indicates that organic fertilizer dealers have negative impact on cover crop adoption. So as the importance of organic fertilizer dealers as an information source increases from moderate level to high level, then, the probability of adoption of cover crops decreases by 0.0837. This negative relationship is possible because organic fertilizer dealers may not be promoting adoption of cover crops. The adoption of cover crops might decrease the demand for organic fertilizers. Therefore, organic fertilizer dealers may not be enthusiastic about promoting cover crop adoption by producers. This negative relationship was also consistent with our predictions.

The only farm related variable that was significant (10% level) was all conservation payments. This was a dummy variable indicating whether a producer received any kind of conservation payment. The relationship was positive (0.54105). If the producer received any kind of conservation payment then the probability of adopting cover crops increased, by almost 0.021 probability points. This was originally expected, because cover crop adoption requires extra time and money. So by getting extra money, producers may be more willing to adopt this agricultural technology. The positive relationship between conservation payments and cover crop adoption was consistent with findings of other studies (Larson et al., 2001).

4.2 SECOND STAGE – TOBIT MODEL

Table 4.2 summarizes results of the tobit model, where nitrogen use by producers is the dependent variable. The model was significant at 1% level and included 128 observations. The significance of the model was based on the F test (Probability > 0.0037).

Recall that the mean amount of nitrogen use by producers, who responded to this study on their highest yielding corn field for 2008 corn production, was 53.4 pounds per acre. This number was calculated including the nitrogen from all sources and different types of nitrogen containing fertilizers and manure animals.

To better describe the marginal effects of different variables on nitrogen use by US producers, marginal decomposition was used, which was suggested by McDonald and Moffitt (1980).

Marginal effects were divided into 3 parts. The first one shows the marginal effects for only the producers who had already adopted cover crops. The second shows marginal effects for producers who did not adopt the technology. The third shows what probability effect the variable has on nitrogen use.

Table 4.2 – Results of Second Stage, Tobit Model

Nitrogen	Coef. (Standard Error)	Marginal Effects (Standard Error)		
		Probability (%)	Adopters	Non-adopters
Predicted values of cover crop*	-103.885 (58.31332)	-0.26174* (0.14488)	-41.4979* (23.444)	-58.49963* (33.115)
Education	-17.3033 (19.77046)	-0.0436 (0.0441)	-6.91195 (7.78841)	-9.743772 (10.953)
Farm size	-0.00129 (0.005642)	-0.00000326 (0.00001)	-0.00052 (0.00225)	-0.0007281 (0.00317)
Farm income	-1.50069 (1.349994)	-0.00378 (0.00351)	-0.59946 (0.54769)	-0.8450643 (0.77449)
Livestock	47.29731 (31.22319)	0.119759 (0.07611)	18.13557 (11.223)	25.30035 (15.364)
Tile drainage	-30.9155 (28.62491)	-0.07805 (0.06598)	-12.1758 (10.985)	-17.10483 (15.334)
Slope (>12%)**	55.25013 (27.00847)	0.132881* (0.07014)	24.42105* (13.154)	34.73399* (18.697)
Rented field**	-59.1088 (27.57518)	-0.14939** (0.06431)	-22.6393** (10.005)	-31.54559** (13.712)
Off farm work**	-17.2369 (10.08983)	-0.04343 (0.02669)	-6.88545* (4.04538)	-9.706419* (5.71111)
All conservation payments	-10.2348 (25.04959)	-0.02583 (0.06376)	-4.05657 (9.88765)	-5.709642 (13.904)
Intercept/constant	149.4664 (73.65398)	N/A	N/A	N/A

* - 10% significance, ** - 5% significance

Rented field, a dummy variable, was the only significant (5% level) socio-economic variable. If the field is rented that decreases the probability of nitrogen use by all producers by 0.15%. That also decreases the nitrogen use by producers who adopted and who didn't adopt cover crops by 22.6 and 31.5 pounds per acre, respectively. This negative relationship had the expected sign. This can be interpreted by the fact that when they rent the field they were less interested in nitrogen content of the field. Or by renting the field producers don't have enough money left for more nitrogen use. So they're using less nitrogen then it is required.

The only significant (5% level) demographic variable in the model was off farm work. The variable had a negative (-17.2369) impact on nitrogen use. This shows that there is negative relationship between off farm work and nitrogen use. This negative relationship is possible, because when producers work (paid) more days off farm, they have less time to work in the farm. As producers have less time in the farm and nitrogen use requires time, producers are using less nitrogen.

Slope, a farm-related variable, was significant at the 5% level. The relationship was positive (55.25013). This variable was a dummy variable showing whether the field had more than a 12% slope or not. If the field has more than a 12% slope that increases the probability of using more nitrogen by 0.0132 by all producers. That also increases nitrogen use by producers by 24.4 and 34.7 pounds per acre for producers who adopted and producers who didn't adopt cover crops respectively.

This positive relationship can be explained by the fact that if the field has more than a 12% slope, then there is more likely to be higher nitrogen leak than in the fields with lesser slope. We can conclude that producers knowing about this fact they tend to use more nitrogen on the fields with higher slopes.

The variable, predicted values of cover crop, was negative (-103.885) and significant (10% level). This showed that cover crop adoption decreased nitrogen use by producers as it has been proven by field studies (Tonito et al. 2006, Sainju et al. 2001, Sainju et al. 2002, Kramberger et al. 2009). Marginal effects shows that nitrogen use by producers, who already adopted cover crops, if they adopt cover crop on more acres of land, will decrease by 41.5 pounds per acre (this is true only for newly adopted fields). This number was even higher for the producers, who didn’t adopt cover crops. The analysis show that if they adopt cover crops, the nitrogen will decrease by 58.5 pounds per acre for adopted acres.

The other portion of marginal decomposition is the probability effect on adoption. The results show that if the producers adopt cover crops, then it will decrease the probability of using nitrogen by 0.262. This value is calculated for all the producers regardless of whether they adopted or did not adopt cover crops.

This result is in compliance with our predicted outcome. Different field research has shown that cover crop adoption decreases soil nitrogen requirements (Tonito et al. 2006, Sainju et al. 2001, Sainju et al. 2002, Kramberger et al. 2009), so this also can imply that producers, knowing about the effects of cover crops on soil nitrogen, are using less of it. We also know that cover crop adoption is associated with more farming time and more expenses, so it is possible that by adopting cover crops, producers don’t have more time and funds to use the amount of nitrogen they intended to use.

CHAPTER 5: SUMMARY AND CONCLUSIONS

In recent years, there were loads of negative impacts on environment due to increase in population, changes in technologies, and agricultural practices. Thus environmental degradation, like land erosion, nitrogen leaching to water sources, has become a huge topic. In this aspect agriculture was being seen as a potential source for greenhouse gas mitigation through carbon sequestration, among others.

The agricultural sector can contribute to economic viability of many rural areas and to food security. As consumer tastes and preferences has changed towards healthier food, environmental concerns increased as well as food safety requirements, agronomic practices have changed gradually to provide not only food and fiber but also public goods and other beneficial services from agriculture. The term "Multifunctional Agriculture" was given to new agricultural practices that provide not only food and fiber to consumers, but also many public goods and services or externalities like land conservation, maintenance of landscape structure, biodiversity preservation, nutrient recycling and loss reduction, among others (Boody et al. 2005; Yrjola and Kola 2004). The elements of multifunctional agriculture are externalities and, in most common cases, public goods that are produced jointly with food or fiber in an agricultural process.

Due to the increase in environmental concerns, changes in consumer tastes and preferences there was increase in interest in organic farming, which is assumed to capture the environmental benefits of agricultural systems (Greene and Kremen, 2002).

Though many differences and uncertainties associated with organic production (Greene and Kremen, 2002) organic crops can receive price premiums of anywhere 10 to 200% or more over conventionally grown products. These higher prices can translate to higher profits for organic producers (University of Kentucky/CES, 2007, and Welsh, 1999). This was one of the main reasons why many conventional producers shifted to towards organic production

(Bertramsen and Dobbs, 2001).

Organically produced corn also had higher prices than conventionally produced corn. Heiman and Peterson (2008) concluded that organic corn premiums exceeded conventional prices by almost 100%.

The view of multifunctional agriculture is very broad, but different agricultural technology adoptions are the major part of it. Agricultural technology adoptions include but are not limited to furrow disking reduces water consumption and improved yield and net returns (Nuti et al. 2009). New technology practices adopted by agricultural producers can include good agrarian practices, irrigation scheduling, water saving, conservation tillage, organic farming, erosion reduction, nitrogen fertilization, plastic covered horticulture and cover cropping, among others (Bertuglia et al. 2006). According to Blazy et al. using such innovations led to both production and environmental benefits.

Cover cropping is one type of agricultural technology adoption. It was proven by many researchers that cover crops can positively affect soil properties and can improve crop development and yield. Sainju et al. (2002) showed that cover crops, in tomatoes for example, could influence soil properties, crop yield and growth (both above and below ground biomass). They also showed that cover crops effect on soil carbon sequestration and microbial biomass and activities by providing additional residue carbon to soil (Sainju et al. 2007).

Though some studies showed that sometimes there is no statistically difference in yields between cover crop and non-cover crop treatments (Ritter et al. 1998), the majority of research indicated that cover crops helped reduce nitrogen leaching. Others showed that cover crops reduced soil N_{min} content in autumn and in spring (Kramberger et al. 2000). Steenwerth and Belina (2004) described how cover crops enhanced the soils' capacity for supporting greater microbial biomass nitrogen, potential nitrogen mineralization, and the microbiological function of nitrification and denitrification.

Use of cover crops is very important ingredient in organic farming as well due to fertilizer requirements in organic farming. Teasdale and Mohler (2000) determined that using cover crops can decrease weed population in organically produced crops. Kuepper (2003) concluded that crops reduce nitrogen leaching by absorbing nitrogen from the atmosphere.

Many field studies have been done in the field showing that cover crops really have a positive impact on many features of the field. But there was no economic analysis to see whether cover crops have any significant impact on nitrogen use by producers (our study was conducted among organic producers in Midwestern United States. So there were four objectives in this work;

1) Identify the determinants of cover-crop adoption,

2) Estimate the change in the probability of adoption of cover crops due to farm, regional, and operator characteristics,

3) Analyze how nitrogen management rate varies by farm for adopters or non-adopters of this technology, and

4) Estimate the change in intensity of decrease in nitrogen use adopters and non-adopters of cover crops due to farm, regional, and operator characteristics.

5.1. SUMMARY OF RESULTS

Two-stage model was used for this analysis; probit and tobit models and marginal effects.

In the first stage, probit model, there were eight variables that had significant effect on cover crop adoption. Producer’s age was significant and had positive effect on adoption of cover crops. This showed that older producers are more likely to adopt cover crops. Years of experience had negative impact on adoption. While experience squared was significant as well.

We calculated that the relationship between years of experience and cover crop adoption changed its sign when the operator had at 50 years of experience.

Farm income was significant as well. It had negative impact on cover crop adoption. As farm income increases (in $100,000) there is less probability (0.13) that producers will adopt the technology of cover crops.

From socio-economic variables that were significant were producers relying on cover crops and organic fertilizer dealers as information sources when making nitrogen management decisions. Other producers (who grow cover crops) as information source when making nitrogen management decisions tend to be significant and positive factor for cover crop adoption. This shows that producers trust other producers for technology adoption. Unlikely to other producers (who grow cover crops), organic fertilizer dealers as information source when making nitrogen management decisions have negative impact on cover crop adoption. This shows that fertilizer dealers are not eager to promote cover crops, because it may hurt their business.

The only farm-related variable that was significant in the model was conservative payments. The relationship was negative, which showed that if producers got an extra payment for different activities, they were more likely to adopt cover crops. In this case, the probability of adopting cover crops increases by 21%.

After analyzing what factors were affecting on cover crop adoption, there was a need to see how cover crop adoption itself effects on nitrogen use by producers. Instead of counting single marginal effects, marginal effects were divided into 3 parts, using McDonald's and Moffitt's marginal decomposition (1980).

The variable, predicted values of cover crops, was significant at 10% and had negative impact on nitrogen use by producers. This result economically proved that cover crops really decreased nitrogen use in the field. If producers had already adopted cover crops and they continue to adopt, then nitrogen will decrease by 41.5 pounds per acre. This number was 58.5 pounds per acre if producers hadn't adopted the technology. If producers had already adopted cover crops than the probability of nitrogen use decreased by 26.2%.

Slope was also significant (at 5%) and had positive impact on nitrogen. If the field had, more than 12% slope that increased the probability of using more nitrogen by 12.3% by all producers. For the producers who adopted and didn't adopt cover crops this this fact increases nitrogen use by producers by 24.4 and 34.7 pounds per acre respectively.

The dummy variable, showing whether the field is rented or not, was the only socio-economic variable. If the field was rented, that decreased the nitrogen use by 22.6 and 31.5 pounds per acre for producers who adopted and didn't adopt respectively. That also decreased the probability of nitrogen use by producers.

The last variable that was significant at 5% was off-farm work by producers. If producers did more paid work off the farm that decreases the probability of nitrogen use by producers. This also decreases the nitrogen use by producers.

5.2. CONCLUSIONS

This study provides analysis about factors affecting cover crop adoption. And this, to our knowledge, this is the first study showing how much cover-crop adoption decreases the nitrogen use by producers econometrically. Several demographic, socio-economic, and farm related variables, were significantly affecting the adoption of cover crops among organic producers;

- Operators' age, farm size, conservative payments, and other producers relying cover crops as an information source variable for nitrogen management had significant and positive effect on adoption of cover crops,

- While years of experience and total farm income and organic fertilizer dealers as an information source variable for nitrogen management had significant and negative effect on cover crop adoption.

The next stage of the analysis provided us with information about how much cover crop adoption had an impact on nitrogen use by producers alongside with other demographic, socio-economic, and farm-related variables;

- The results showed that producers with adoption of cover crops tended to use less nitrogen than without adoption, and the adoption decreases the probability of using nitrogen as well,
- Slope of the field also determined the amount of the nitrogen use in the field. If the field has more than 12% slope than producers tend to use more nitrogen, most probably because of the nitrogen leakage.
- It also was evident that the producers who rented the field use less nitrogen in those fields,
- The other significant result was the fact of working outside the farm. If the producers did more paid work off the farm, then they used less nitrogen per acre.

Those results showed that cover crops really had significant and negative effect on nitrogen use by producers. These analyses were done among the organic producers in Midwestern U.S. region. It will be interesting to see how the adoption of cover crops affects nitrogen use among conventional producers as well.

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APPENDIX A: SURVEY SENT TO ORGANIC PRODUCERS IN MID U.S. REGION

Section VII. Comments

46. Please tell us anything else you would like us to know about you, your farming operation, your experience, and your vision for the future of agriculture in your area.

47. What do you think is the appropriate solution to water quality problems?

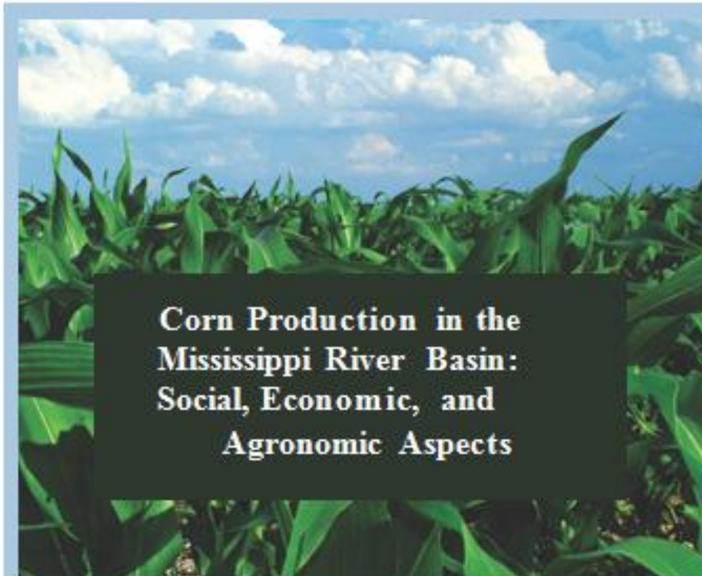
48. Would you like to receive a summary of findings from this research?

○ Yes (a copy will be mailed to you) ○ No

Thank you for your time and participation in this project.

Please return the survey in the enclosed, postage-paid envelope or send to:

Professor Mark David
University of Illinois at Urbana-Champaign
Department of Natural Resources and Environmental Sciences
W-503 Turner Hall
1102 S. Goodwin Av.
Urbana, IL 61801



Corn Production in the Mississippi River Basin: Social, Economic, and Agronomic Aspects

Spring 2009

Section I. General Information

1. Were you responsible for making management decisions on a harvested corn crop in 2008?
   - ○ Yes ⇨ *Please go to question 2*
   - ○ No ⇨ *Please ask the person who made management decisions on corn in 2008 to fill out this survey. If you cannot do so, please return this questionnaire in the postage-paid envelope provided and indicate why. Thank you!*

   Reason for returning the questionnaire:
   - ○ Retired from farming
   - ○ Did not grow corn in 2008
   - ○ Never farmed
   - ○ Other *(please specify)* ______________

Section II. Farm Information

2. Of the total acres in your farming operation on December 31, 2008, how many were:

	ACRES
Rented or leased from others?	
Cropland (planted or cropped including hay land)?	
In fruit, vegetable, nursery, and floriculture crops?	
Cropland used to raise certified organic crops?	
↳ If you have certified land, please write the year you were first certified:	year
Cropland planted to over-wintering plants - winter grains, perennial forages and annual cover crops (crops not harvested) or green manure crops (nitrogen-fixing cover crops)?	
In field borders, grassed waterways, buffers, and other areas associated with conservation practices but not cropped?	
In pasture and rangeland?	
Enrolled in the Conservation Reserve Program (CRP), the Wetland Reserve Program (WRP) or similar program?	
In woodland and forest?	

3. Of the cropland you farmed in 2008, how many acres were planted to:

CORN	SOYBEANS	SORGHUM	COTTON	RICE	ALFALFA HAY	OTHER HAY
acres	acres	acres	acres	acres	acres	acres

SMALL GRAINS	OIL SEEDS	SUGARCANE, SUGARBEETS	DRY LENTILS, PEAS, BEANS	PEANUTS	VEGETABLES	ALL OTHER CROPS
acres	acres	acres	acres	acres	acres	acres

36. Indicate your agreement or disagreement with the following statement: My soil fertility management practices have a large effect on water quality. *Select one.*

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
○	○	○	○	○

Section VI. Operator Characteristics

37. How many years have you been farming? ______

38. What is your current age? ______

39. Are you male or female? ○ Male ○ Female

40. What is the highest level of education you have completed?
   - ○ Less than high school diploma
   - ○ High school or equivalent (such as GED)
   - ○ Some college or vocational training
   - ○ College bachelor degree
   - ○ Advanced degree

41. What is your ethnicity/race? *Select all that apply.*
   - ○ African American or Black
   - ○ Asian or Pacific Islander
   - ○ Latino or Hispanic
   - ○ American Indian
   - ○ White
   - ○ Other *(please specify)* ______________

42. How many days did you do paid work off farm for at least four hours during 2008? *Select one.*

None	1 - 49 days	50 - 99 days	100 - 199 days	200 days or more
○	○	○	○	○

43. How is your farming operation organized? *Select one.*
   - ○ Family or individual (sole proprietorship)
   - ○ Legal partnership
   - ○ Incorporated under state law
   - ○ Other, such as estate or trust *(please specify)* ______________

44. Do any family members plan to take over your farming operation when you retire? *Select one.*
   - ○ Yes ○ No ○ Do not know

45. What was your total household income, including net farm profit, in 2008? *Select one.*
   - ○ Less than $30,000
   - ○ $30,000 - $59,999
   - ○ $60,000 - $89,999
   - ○ $90,000 - $119,999
   - ○ $120,000 - $149,999
   - ○ $150,000 - $179,999
   - ○ $180,000 - $209,999
   - ○ $210,000 - $239,999
   - ○ $240,000 - $269,999
   - ○ $270,000 or more

Please continue to back cover.

33. Your **civic community** is considered a geographic locale, typically a town. Considering the civic community where you live, indicate if you agree or disagree with the following statements:

My civic community...	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
requires that all members think and act the same	○	○	○	○	○
promotes innovation and member learning	○	○	○	○	○
engages in *constructive* criticism	○	○	○	○	○
has small differences in wealth	○	○	○	○	○
invests private resources for the public good	○	○	○	○	○
has closed decision-making structures	○	○	○	○	○

34. Your **professional network** is a community of individuals and organizations who do not necessarily live in the same town but interact regularly because of shared professional interests. Considering your professional network, indicate if you agree or disagree with the following statements:

My professional network...	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
requires that all members think and act the same	○	○	○	○	○
promotes innovation and member learning	○	○	○	○	○
engages in *constructive* criticism	○	○	○	○	○
has small differences in wealth	○	○	○	○	○
invests private resources for the public good	○	○	○	○	○
has closed decision-making structures	○	○	○	○	○

35. Consider nutrients (nitrates and phosphorus), pesticides, bacteria, sediments or cloudiness, weeds, and fish. How do you rate the water quality of the following:

	Very poor	Poor	Moderate	Good	Very good
Your drinking water	○	○	○	○	○
Your farm's surface water	○	○	○	○	○
Your farm's ground water	○	○	○	○	○
Local waters used for drinking	○	○	○	○	○
Local waters used for recreation	○	○	○	○	○
Your state's water resources	○	○	○	○	○

4. For each of the following types of livestock, please indicate the total number sold in 2008 and the total number on hand at the end of 2008.

		Total number sold or removed in 2008	On hand Dec. 31, 2008
Dairy cattle (cows, heifers, steers, calves, bulls)			
Beef cattle (cows, heifers, steers, calves, bulls)			
Hogs and pigs			
Poultry *(please specify)*			
Other *(please specify)*			

5. What was the total dollar amount your farming operation received in 2008 from:
The sum should equal your total income from farming.

	DOLLARS
Sales of all crops after subtracting the costs of marketing	$
Sales of livestock and livestock products minus costs or inventory change	$
All commodity program payments including disaster payment (taxable amount)	$
All conservation program payments (CRP, WRP, EQIP, CSP, etc.)	$
Income from renting or leasing land	$
All other farming income	$

6. What was the total dollar amount for the following farming expenses in 2008:
The sum should equal your total farming expenses.

	DOLLARS
Fertilizer and lime	$
Conservation program related expenses	$
All other production related expenses	$

7. Have you expanded or renovated tile drainage on your farm in the last 10 years?
○ Yes ○ No

Section III: Field Information - Highest Yielding Corn Field

*For this section of the questionnaire, we want you to consider one particular field in your farming operation - specifically, the **highest** yielding field (bushels/acre) in which you grew corn in 2008.*

8. For this **highest** yielding 2008 corn field:

My field identification name or number is: ______________

It is located in: ______________ county ______________ township

______________ range ______________ section

The area of cropland in this field is: ______ acre

The dominant soil texture in this field is: ______________

The dominant soil series is: ______________

The corn yield in this field for 2008 was: ______ bushels/acre

Did you rent/lease this field in 2008? ○ Yes ○ No

↳ If so, what was the cash rent you paid per acre? ______ $/acre

9. Please describe this field. *Select all that apply.*

- ○ This field has artificial subsurface (tile) drainage
- ○ Temporary or permanent streams, waterways or ditches located within or adjacent to this field
- ○ This field is mostly flat (0-2%)
- ○ This field has gentle slopes (2-6%)
- ○ This field has moderate slopes (6-12%)
- ○ This field has steep slopes (greater than 12%)

10. Define the crop rotation in this **highest** yielding corn field over the last five years. Write in the crops planted each year, including double crops, and indicate your use of no-till and manure in this field.

	2008	2007	2006	2005	2004
Crops	CORN				
No-till used	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No
Manure applied	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No

11. What seed variety was used on the majority of this **highest** yielding corn field in 2008?

____

30. How would you rate the knowledge of **off-farm** service providers available to you for each of the topics below? *Select one response per row.*

	Level of Knowledge				
	None	Low	Moderate	High	Very High
Nitrogen credit for manure or legumes (including soybeans)	○	○	○	○	○
Optimizing plant available N	○	○	○	○	○
Experimentation (formal or informal)	○	○	○	○	○
Farm economics	○	○	○	○	○
Seeking out scientific information	○	○	○	○	○
Judging soil health or soil quality	○	○	○	○	○
Growing winter cover crops that are not harvested	○	○	○	○	○
Growing winter grains	○	○	○	○	○
Organic production methods	○	○	○	○	○
Protecting water quality	○	○	○	○	○
Tailoring management to physical variation within fields	○	○	○	○	○

31. For each type of N listed below, please indicate how your current N management for corn has changed **relative to five years ago**. *Select one response per row.*

	I use less per acre than 5 years ago	I use the same per acre as 5 years ago	I use more per acre than 5 years ago	Does not apply to my case
Commercial N	○	○	○	○
Legume N	○	○	○	○
Manure N	○	○	○	○

32. For each type of N listed below, how do you expect your N management for corn will change over the **next five years**? *Select one response per row.*

	I will use less per acre than now	I will use the same per acre as now	I will use more per acre than now	Does not apply to my case
Commercial N	○	○	○	○
Legume N	○	○	○	○
Manure N	○	○	○	○

Section V. Sources of Information and Decision Making Context

27. Consider the information sources you use to make decisions about nitrogen management. Please rate the level of importance of each potential information source below. *Select one response per row.*

	Level of Importance: None	Low	Moderate	High	Very High
Farmers relying on commercial N	○	○	○	○	○
Farmers relying on cover crops, manure or legumes	○	○	○	○	○
Buyer(s) of your crops	○	○	○	○	○
Landlord(s)	○	○	○	○	○
Family, friends, or neighbors	○	○	○	○	○
Cooperative Extension	○	○	○	○	○
Conservation agency personnel (NRCS or SWCD)	○	○	○	○	○
Independent consultants	○	○	○	○	○
Fertilizer/input dealers	○	○	○	○	○
Organic fertilizer dealers	○	○	○	○	○
Mainstream farm organizations (e.g. Farm Bureau)	○	○	○	○	○
Organizations promoting cover crops and legumes	○	○	○	○	○
Other *(please specify)* ____________	○	○	○	○	○

28. Please identify all agricultural or conservation organizations to which you belong and indicate in the column on the right if you have ever occupied a leadership role in these organizations.

Organization	Leadership Role
____________	
____________	○
____________	

29. What is the level of knowledge available to you (either you or the people who work with you) for each of the topics below? *Select one response per row.*

	Level of Knowledge: None	Low	Moderate	High	Very High
Nitrogen credit for manure or legumes (including soybeans)	○	○	○	○	○
Optimizing plant available N	○	○	○	○	○
Experimentation (formal or informal)	○	○	○	○	○
Farm economics	○	○	○	○	○
Seeking out scientific information	○	○	○	○	○
Judging soil health or soil quality	○	○	○	○	○
Growing winter cover crops that are not harvested	○	○	○	○	○
Growing winter grains	○	○	○	○	○
Organic production methods	○	○	○	○	○
Protecting water quality	○	○	○	○	○
Tailoring management to physical variation within fields	○	○	○	○	○

12. For each of the following types of fertilizer, please indicate the total amount applied (lbs or gals of N fertilizer per acre) and when it was applied to this highest yielding corn field for the 2008 corn crop.
If you used no commercial N, skip to question 13.

Commercial Fertilizer	Fall 2007	Spring 2008: Pre-plant/at planting	Spring/Summer 2008: Post-Plant/side dress
Anhydrous ammonia	___ lbs/acre	___ lbs/acre	___ lbs/acre
Urea	___ lbs/acre	___ lbs/acre	___ lbs/acre
MAP	___ lbs/acre	___ lbs/acre	___ lbs/acre
DAP	___ lbs/acre	___ lbs/acre	___ lbs/acre
Liquid Nitrogen (28%N)	___ gals/acre	___ gals/acre	___ gals/acre
Liquid Nitrogen (32%N)	___ gals/acre	___ gals/acre	___ gals/acre
Other *(please specify analysis):* ____________	___ lbs/acre	___ lbs/acre	___ lbs/acre

13. Was manure applied to this field for the 2008 corn crop?
- ○ Yes ⇒ How many acres in this field received manure? ________ acres
- ○ No ⇒ *Skip to question 17*

14. When was manure applied in this field for this corn crop? *Select all that apply.*
- ○ 2007 Fall/Winter ○ 2008 Winter/Spring

15. What types of manure were applied to this field? *Select all that apply.*
- ○ Dairy cattle ○ Hog or swine
- ○ Beef cattle ○ Poultry
- ○ Other (please specify) ____________________

16. What was the total amount of manure applied to this field for the 2008 corn crop?
Please record the volume and indicate the appropriate units.

______________ ○ Tons ○ Gallons

17. Was a cover crop (crop not harvested) or green manure (nitrogen-fixing cover crop) incorporated in this highest yielding corn field for the 2008 corn crop?
- ○ Yes ⇒ *Continue with question 18*
- ○ No ⇒ *Skip to question 21*

18. Which cover crop or green manure was planted in this field prior to the 2008 corn crop? *Select all that apply.*
○ Red clover ○ Alfalfa ○ Vetch ○ Other *(please specify)* ____________

19. When was the cover crop or green manure **planted** in this field before the 2008 corn crop?
____/________ MM/YYYY

20. When was the cover crop or green manure **incorporated** in this field before the 2008 corn crop?
____/________ MM/YYYY

21. For each of the farming practices listed below, we would like you to identify each practice you used on at least half of your fields in 2008. *Select all that apply.*

	Used in at least half of your fields
Yield goal to determine N fertilizer rate for corn	○
N credits for manure or legumes, including soybeans	○
Soil testing to determine N fertilizer rate for corn	○
PSNT, stalk N test, or chlorophyll meter in corn	○
Fall application of N fertilizer for corn	○
Nitrification inhibitor in corn	○
Split application or side-dressing of N fertilizer for corn	○
Fall or winter application of manure for corn	○
Rotation with winter grains	○
Rotation with winter cover crops (crops not harvested)	○
Rotation with frost seeding red clover into a winter grain	○
Buffers or hedgerows on two or more sides	○
Other *(please specify)* ____________	○

Section IV: Field Information - Lowest Yielding Corn Field

For this section of the questionnaire, we want you to consider one particular field in your farming operation - specifically, the lowest yielding field (bushels/acre) in which you grew corn in 2008.

22. For this lowest yielding 2008 corn field:

My field identification name or number is: ____________

It is located in: ____________ county ____________ township

____________ range ____________ section

The area of cropland in this field is: ________ acre

The dominant soil texture in this field is: ____________

The dominant soil series is: ____________

The corn yield in this field for 2008 was: ________ bushels/acre

Did you rent/lease this field in 2008? ○ Yes ○ No

↳ If so, what was the cash rent you paid per acre? ________ $/acre

23. Please describe this field. *Select all that apply.*
○ This field has artificial subsurface (tile) drainage
○ Temporary or permanent streams, waterways or ditches flow within or adjacent to this field
○ This field is mostly flat (0-2%)
○ This field has gentle slopes (2-8%)
○ This field has moderate slopes (8-12%)
○ This field has steep slopes (greater than 12%)

24. Define the crop rotation in this lowest yielding corn field over the last five years. Write in the crops, including double crops, and indicate your use of no-till and manure in this field.

	2008	2007	2006	2005	2004
Crops	CORN				
No-till used	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No
Manure applied	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No	○ Yes ○ No

25. For each characteristic below, please compare this lowest yielding corn field to the high yielding field you described in Section III.

In my lowest yielding 2008 corn field ...	Lower or less	Similar	Greater or more	
Soil fertility is	○	○	○	compared to the high yielding field
Soil organic matter is	○	○	○	compared to the high yielding field
Soil variability is	○	○	○	compared to the high yielding field
Drainage rate is	○	○	○	compared to the high yielding field
Flooding susceptibility is	○	○	○	compared to the high yielding field
Drought susceptibility is	○	○	○	compared to the high yielding field
Weed pressure is	○	○	○	compared to the high yielding field

26. For each management practice listed below, please compare this lowest yielding corn field to the high yielding field you described in Section III.

In my lowest yielding 2008 corn field ...	Lower or less	Similar	Greater or more	
Fall N fertilizer rate for 2008 corn was	○	○	○	compared to the high yielding field
Spring N fertilizer rate for 2008 corn was	○	○	○	compared to the high yielding field
Number of tillage passes for 2008 corn was	○	○	○	compared to the high yielding field
Cost of corn production in 2008 was	○	○	○	compared to the high yielding field

APPENDIX B:
PROJECT STATISTICS, MAILING TIMELINE, AND PROCESSED SURVEYS BY SAMPLE TYPE

Project Statistics

Project initiated	February 7, 2009
Data delivered	June 10, 2009
Data collection started	March 20, 2009
Data collection completed	May 22, 2009
Mode of data collection	Scan-able mail questionnaire
Total surveys processed	446

Mailing Timeline

Mailing type	Date	N
Full mailing (letter, questionnaire, reply envelope)	March 16, 2009	3000
Non-respondent postcard reminder	March 20, 2009	2988
Non-respondent full mailing	April 3, 2009	2560
Non-respondent postcard reminder	April 10, 2009	2538

Processed Surveys by Sample Type

Sample type	Sample size	Number processed
Organic	932	233

APPENDIX C: CALCULATIONS OF N CONTENT USED BY PRODUCERS

```
************CONVERTING FERTILIZER USE IN ACTIVE INGREDIENT TERMS*****************************;
IF V12A1 = . THEN AI_AMMP_F7 = 0; ELSE AI_AMMP_F7 = V12A1*0.82;
IF V12B1 = . THEN AI_UREA_F7 = 0; ELSE AI_UREA_F7 = V12B1*0.4665;
IF V12C1 = . THEN AI_MAP_F7 = 0; ELSE AI_MAP_F7 = V12C1*0.1218;
IF V12D1 = . THEN AI_DAP_F7 = 0; ELSE AI_DAP_F7 = V12D1*0.18;
IF V12E1 = . THEN AI_LIQN_F7 = 0; ELSE AI_LIQN_F7 = V12E1*10.65*0.28;
        *DEFINING WEIGHT MEASURE MULTIPLYING IT WITH DEINSITY OF N = 10.65;
IF V12F1 = . THEN AI_LIQN2_F7 = 0; ELSE AI_LIQN2_F7 = V12F1*0.32*10.65;
        *DEFINING WEIGHT MEASURE MULTIPLYING IT WITH DEINSITY OF N = 10.65;
TOTALN_F7 = AI_AMMP_F7 + AI_UREA_F7 + AI_MAP_F7 + AI_DAP_F7 + AI_LIQN_F7 + AI_LIQN2_F7;

IF V12A2 = . THEN AI_AMMP_S8P = 0; ELSE AI_AMMP_S8P = V12A2*0.82;
IF V12B2 = . THEN AI_UREA_S8P = 0; ELSE AI_UREA_S8P = V12B2*0.4665;
IF V12C2 = . THEN AI_MAP_S8P = 0; ELSE AI_MAP_S8P = V12C2*0.1218;
IF V12D2 = . THEN AI_DAP_S8P = 0; ELSE AI_DAP_S8P = V12D2*0.18;
IF V12E2 = . THEN AI_LIQN_S8P = 0; ELSE AI_LIQN_S8P = V12E2*10.65*0.28;
        *DEFINING WEIGHT MEASURE MULTIPLYING IT WITH DEINSITY OF N = 10.65;
IF V12F2 = . THEN AI_LIQN2_S8P = 0; ELSE AI_LIQN2_S8P = V12F2*10.65*0.32;
        *DEFINING WEIGHT MEASURE MULTIPLYING IT WITH DEINSITY OF N = 10.65;
TOTALN_S8P = AI_AMMP_S8P + AI_UREA_S8P + AI_MAP_S8P + AI_DAP_S8P + AI_LIQN_S8P + AI_LIQN2_S8P;

IF V12A3 = . THEN AI_AMMP_S8PL = 0; ELSE AI_AMMP_S8PL = V12A3*0.82;
IF V12B3 = . THEN AI_UREA_S8PL = 0; ELSE AI_UREA_S8PL = V12B3*0.4665;
IF V12C3 = . THEN AI_MAP_S8PL = 0; ELSE AI_MAP_S8PL = V12C3*0.1218;
IF V12D3 = . THEN AI_DAP_S8PL = 0; ELSE AI_DAP_S8PL = V12D3*0.18;
IF V12E3 = . THEN AI_LIQN_S8PL = 0; ELSE AI_LIQN_S8PL = V12E3*10.65*0.28;
        *DEFINING WEIGHT MEASURE MULTIPLYING IT WITH DEINSITY OF N = 10.65;
IF V12F3 = . THEN AI_LIQN2_S8PL = 0; ELSE AI_LIQN2_S8PL = V12F3*10.65*0.32;
        *DEFINING WEIGHT MEASURE MULTIPLYING IT WITH DEINSITY OF N = 10.65;
TOTALN_S8PL = AI_AMMP_S8PL + AI_UREA_S8PL + AI_MAP_S8PL + AI_DAP_S8PL + AI_LIQN_S8PL + AI_LIQN2_S8PL;
```

```
********************DEFINING NITROGEN IN EACH TYPE OF
MANURE***************************************************************;
IF V15A = 1 AND V15B = . AND V15C = . AND V15D = . AND V15E_O = . AND V16A = 1
THEN N_DAIRY = v16*0.065;                                    *DAIRY LACTATING COW
WEIGHT;
ELSE IF V15A = 1 AND V15B = . AND V15C = . AND V15D = . AND V15E_O = . AND
V16A = 2 THEN N_DAIRY = V16*8.3*0.0005*0.065;      *DAIRY LACTATING COW
VOLUME TO WEIGHT CONVERSION;

IF V15A = . AND V15B = 1 AND V15C = . AND V15D = . AND V15E_O = . AND V16A = 1
THEN N_BEEF = v16*0.0675;                                    *HIGH FORAGE BEEF CATTLE;
ELSE IF V15A = . AND V15B = 1 AND V15C = . AND V15D = . AND V15E_O = . AND
V16A = 2 THEN N_BEEF = V16*8.3*0.0005*0.0675;       *HIGH FORAGE BEEF CATTLE
VOLUME TO WEIGHT CONVERSION;


IF V15A = . AND V15B = . AND V15C = 1 AND V15D = . AND V15E_O = . AND V16A = 1
THEN N_SWINE = v16*0.0842;                                   *GROW-FINISH SWINE;
ELSE IF V15A = . AND V15B = . AND V15C = 1 AND V15D = . AND V15E_O = . AND
V16A = 2 THEN N_SWINE  = V16*8.3*0.0005*0.0842;   *GROW-FINISH SWINE
VOLUME TO WEIGHT CONVERSION;

IF V15A = . AND V15B = . AND V15C = . AND V15D = 1 AND V15E_O = . AND V16A = 1
THEN N_POULTRY = v16*0.0135;                                  *LAYER;
ELSE IF V15A = . AND V15B = . AND V15C = . AND V15D = 1 AND V15E_O = . AND
V16A = 2 THEN N_POULTRY  = V16*8.3*0.0005*0.0135; *LAYER VOLUME TO WEIGHT
CONVERSION;

IF V15A = . AND V15B = . AND V15C = . AND V15D = . AND (V15E_O = 'HORSE' OR
V15E_O = 'HORSE MANURE' OR  V15E_O = 'HORSE AND COMPOST') AND V16A = 1
THEN N_HORSE = v16*0.035;                                     *HORSE;
ELSE IF V15A = . AND V15B = . AND V15C = . AND V15D = . AND (V15E_O = 'HORSE'
OR V15E_O = 'HORSE MANURE' OR  V15E_O = 'HORSE AND COMPOST') AND V16A =
2 THEN N_HORSE  = V16*8.3*0.0005*0.035; *HORSE VOLUME TO WEIGHT
CONVERSION;


IF V15E_O = 'LIQUID SHERRY' AND V16A = 1 THEN N_OTHER = V16*0.065;
ELSE IF V15E_O = 'LIQUID SHERRY' AND V16A = 2 THEN N_OTHER = V16*0.065*8.3;
ELSE IF V15_O = 'COMPOSTED CHICKED MANURE' THEN N_OTHER = V16*0.0135;
ELSE IF V15_O = 'COMPOSTED TURKEY MANURE' THEN N_OTHER = V16*0.014;
ELSE IF V15_O = 'COMPOSTED DAIRY MANURE' THEN N_OTHER = V16*0.0614;



*         IF (V15E_O = 'GOAT MANURE' OR V15E_O = 'SHEEP AND GOAT') AND V16A =
1 THEN N_GOAT =
```

```
ELSE  IF (V15E_O = 'GOAT MANURE' OR V15E_O = 'SHEEP AND GOAT') AND V16A =
1 THEN N_GOAT = *;
IF TOTALN_S8P GE 0 OR TOTALN_S8PL GE 0 THEN NITROGEN =
TOTALN_S8P+TOTALN_S8PL; ELSE NITROGEN = 0;RUN;
```

VITA

Gnel Gabrielyan graduated Armenian State Agricultural University (former Armenian Agricultural Academy) in 2005. He received a Bachelor's degree in Agribusiness and Marketing. He started his Master's program in the Fall 2008 in Department of Agricultural Economics and Agribusiness at Louisiana State University. Now he is pursuing PhD in Economics in Washington State University.