# FACTORS AFFECTING THE ADOPTION OF TILLAGE SYSTEMS IN KANSAS

by

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## ABSTRACT

Concerns about environmental degradation due to agriculture have gained importance as it is associated with soil erosion, health hazards, and ground water pollution. Environment-friendly land use practices have been developed to gain a wide range of environmental benefits including reduced soil erosion, reduced nutrient runoff from crop and livestock facilities, increased biodiversity preservation efforts, and restoration of wetlands and other native ecosystems. No-till is one such practice where soil erosion, nutrient runoff and environmental degradation can be reduced to a certain extent. This study evaluated the factors affecting the adoption of tillage systems in Kansas.

A survey was conducted with a total of 135 participants from four different locations in the state of Kansas between August 2006 and January 2007. The adoption process was modeled as a two-step econometric models consisting of perception and adoption equations to estimate the impacts of demographic variables and farmers' familiarity with and participation in certain conservation programs.

The results for the perception models showed that the farm operators' perceptions regarding whether BPM installation and management is unfair to producers or not and whether environmental legislation is often unfair to producers do not vary systematically across farm size, producers' familiarity and participation in conservation programs, or other demographics considered in the study. On the other hand, their perceptions regarding how polluted their water supplies varied by their thoughts on relative profitability across various tillage practices, their primary occupation, and their familiarity with conservation programs. Specifically, the results suggested that those who

regarded no-till practices to be more profitable than other tillage practices or whose primary occupation was farming-related tended to believe that ground water was not polluted, and those who were less familiar with available conservation programs tended to believe that surface water s were not polluted.

The adoption model results suggested that farmers with greater operating acreage, those who perceived that no-till was more profitable than other tillage systems, and those with greater familiarity with and participation in existing conservation programs were more likely to adopt more conservation tillage systems, all else equal. Further, perceptions of fairness of environmental regulations or the level of pollution did not impact the tillage choices.

## TABLE OF CONTENTS

## List of Figures

## List of Tables

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# Chapter 1: Conservation Tillage Systems

## 1.1. Introduction

In current day agriculture, a major factor contributing to yield loss is soil water losses through surface runoff and evaporation. Tillage is the process which disturbs the entire top layer of the soil (Houghton and Chapman, 1986). Tillage operations were previously carried out mainly for weed control (Halpin and Bligh, 1974). But currently available herbicides and the development of their effective and safe application have changed the patterns of tillage on agricultural lands. Since the 1980's concern about environmental degradation due to agriculture has gained importance as it is associated with soil erosion, health hazards, and groundwater pollution (Bouchard, Williams, and Surampalli, 1992; Bouwer, 1990; O'Neil and Raucher, 1990). In agriculture worldwide and particularly in the Midwest, the adoption of environmentally friendly land use practices have been gradually increasing aiming to gain a wide range of environmental benefits that include reduced soil erosion, reduced nutrient runoff from crop and livestock facilities, habitat restoration for endangered species, increased biodiversity preservation efforts, restoration of wetlands and other native ecosystems and reduced nitrogen loading (Wu et al., 2003).

In order to accomplish the task, policymakers and environmentalists believe that there is an urgent need for a change in the agricultural land management practices towards the adoption of "best management practices" (BMPs) (Traore, Landry, and Amara, 1998). And some of such agricultural land management practices include crop rotation, alternate management practices on cultivated land, and conservation tillage practices. Besides, numerous federal and state incentive-based programs were introduced so as to improve several environmental amenities. Some of the programs were the Conservation Reserve Program (CRP), the Environmental Quality Incentive Program (EQIP), and the Wetland Reserve Programs (Wu et al., 2003).

CRP provides the enrolled producers with assistance in technical and financial aspects to resolve soil, water, and other natural resource issues on their lands in a eco-friendly and cost-effective manner. The program works closely with producers to encourage their adopting environmentally friendly practices following the Federal, State, and tribal environmental laws. CRP is funded through Commodity Credit Corporation (CCC), administered by the Farm Service Agency, where the Natural Resource Conservation Service (NRCS) at the U.S. Department of Agriculture (USDA) provides the technical land eligibility determination, conservation planning and practice implementation (USDA-NRCS, 2008a).

EQIP was reauthorized by the Farm Security and Rural Investment Act of 2002. Similar to CRP, this program also provides technical and financial assistance to the farmers to implement structural and management practices on eligible agricultural lands. This program provides incentives and cost shares as contracts for implementing conservation practices. The contracts range from a minimum of one year to a maximum of ten years. EQIP also follows the NRCS standards adapted for local conditions (USDA-NRCS, 2008b).

The Wetland Reserve Program is a voluntary program which helps the landowners protect and restore the wetlands on their property. The technical and financial assistance for this program is also provided by NRCS with the aim of achieving the maximum wetland functions and values, and optimize the wildlife on every acre of land enrolled in this program (USDA-NRCS, 2008c).

Conservation tillage practices primarily focus on reducing soil erosion and influencing the water movement through soil (US Office of Technology Assessment, 1990). Conservation tillage is defined as system which retains the crop residues on the soil surface in order to maintain rough soil-surface, control soil erosion and achieve good soil-water relations (Allmaras et al., 1966; Mannering and Fenster, 1983). Specifically, if a tillage system leaves more than 15 percent of crop residue or more than 500 pounds of grain residue per acre, the system is considered a conservation tillage system (Ali, Brooks, and McElroy, 2000).

No-till is one of the conservational tillage systems. No-tillage avoids any kind of tillage to the soil before the seeds are sown or seedlings are planted and can reduce soil erosion by 80 to 90 percent compared to conventional tillage (Griffith, Mannering, and Box, 1986). As no-till system conserves soil moisture, it is expected that the crop yields from no-till system will be equal to or greater than those from conventional tillage on well drained soils in the US (Mannering and Amemiya 1987).

No-tillage is considered to be a good practice because it reduces soil erosion, production costs, labor requirement, machinery operating costs, and machinery fixed costs compared to both conventional tillage and other conservation tillage practices. However, its adoption has been slower than expected (Krause and Black, 1995). In 1974, the USDA predicted that 45 percent of US planted cropland will adopt no-till system by the year 2000 (Phillips et al., 1980). The percentage of planted cropland under no-till in the year 1974 was 1.7 percent (Phillips et al., 1980) and it increased to 3.3 percent in

1983, then to 4.4 percent in 1989 (USDA-NASS). The real expansion of no-till system started from the year 1989 where no-till system increased to 6.0 percent in 1990 and then to 9.9 percent in 1992 (USDA-NASS). The 2007 Amendment to the National Crop Residue Management Survey Summary listed no-till acres at 65.5 million acres out of 276 million acres (i.e., 23.7 percent of the total cropland acreage). The 2004 Conservation Technology Information Center No-till Survey listed Kansas no-till acres at 4.2 million.

## 1.2. Objective of the Study

The objective of this study is to identify the factors affecting the adoption of no-tillage system in the state of Kansas. The factors considered in the study include farm characteristics, such as farm size and location, relative profitability of no-till and tillage systems; familiarity of and participation in major conservation programs, and farmer characteristics.

To objective was addressed using recent survey data collected from Kansas farmers. The adoption process was modeled as a two-step econometric models consisting of perception and adoption equations, and was estimated using the survey responses.

## 1.3. Organization of the Study

The remainder of the thesis is organized into four chapters. Chapter 2 provides a broad literature review on technology adoption with some examples, methodological frameworks, and factors affecting the adoption process including sections on the adoption of no-tillage system, comparison of no-tillage system to other tillage systems and the factors affecting the conversion of conventional tillage to no-tillage. Chapter 3 explains the methodology and procedure used for the study. Chapter 4 reports the results of the study. Chapter 5 includes a summary and conclusion.

# Chapter 2: Literature Review on Technology Adoption

This chapter provides a review of literature on technology adoption. Following a brief introduction the term adoption is first defined and the importance of technology adoption is discussed. Then studies on examples of technology adoption, the paths of technology adoption, and the factors affecting the general process of adoption are reviewed. A subsequent section reviews studies on no-tillage systems. The chapter concludes with a summary of questions unanswered on this topic

## 2.1. Introduction

Innovative technologies have attracted the farmers throughout our history around the world, particularly in the less developed countries (LDC's) as new technologies provide an opportunity to increase production and income substantially. This is mostly because the LDC's citizens derive their livelihood from agricultural production. Some of the technologies introduced include High Yielding Varieties (HYV), Genetically Modified Crops, BT Cotton, and Conservation Tillage practices. But the outcome of these technologies has fallen short of their expected success as measured by the observed rates of adoption. In general, the constraints associated with the rapid adoption of innovation technologies are lack of financial support, improper info-structure, inadequate incentives, inadequate farm size, aversion to risk, insufficient human capital, the absence of sophisticated equipment to relieve the labor shortage, untimely or inadequate supply of inputs and complementary inputs, and inappropriate transportation infrastructure (Feder, Just, and Zilberman, 1985)

Many economic development projects focused on eliminating these constraints by introducing institutions to provide credit, information, timely supply of inputs and complementary inputs, improved infrastructure, and improved market networks among others. This elimination was expected to result not only in adoption of innovative technologies but also in change of crop composition, which was expected to increase the average farm income. But the expectations have been only partially fulfilled.

From the past experiences, the immediate and uniform adoption of innovative technologies in agriculture is very rare (Feder, Just, Zilberman, 1985). This is primarily because adoption behavior differs across the socio economic groups and over time. And, usually most of the innovations and improvements are received by a very small group of farmers. This is because the innovative technological changes are associated with high capital investments and also requires a certain farm size in order to ensure profits as it is correlated to the machinery and equipment investment (Hategekimana and Trant, 2002). However, there are other relatively inexpensive technological innovations in agriculture, such as balanced feed, soil testing, and raising of new varieties of hybrids (Griliches, 1957).

In order to increase the rate of adoption of innovative technologies, it is important that these innovations either reduce production costs or increase revenue. The cost of production can be reduced if the cost of adopting the new technology is low and this can be achieved by decreasing required inputs, providing technical assistance, and providing information on research and development of the new technology. For reference, revenue can be increased by providing access to the markets, promoting crops, subsidizing private consumption, and increasing the government purchases (Van Ravenswaay and Blend, 1997).

## 2.2. Defining Adoption

Rogers (1962) defines the adoption process as "the mental process an individual passes from first hearing about an innovation to the final adoption" (p. 17). A quantitative definition which distinguishes the individual (farm level) adoption and aggregate adoption was given by Schultz (1975): final adoption at the level of the individual farmer is defined as the degree of use of new technology and its potential, where as in the context of aggregate adoption behavior the diffusion process is defined as the process of spread of new technology within a region.

The increasing interest in innovation and adoption of new technologies is primarily because these innovative technologies improve the key economic factors of productivity and efficiency (Hategekimana and Trant, 2002). Moreover, technology is a means to improve the socio economic conditions of the society. It is in the diffusion state that new technologies produce impact on the economy (Feder, Just, Zilberman, 1985). Being the first to adopt a new, efficient technology means being able to enjoy the gains before rivals. In other words, technical changes improves the productivity and the extent of this effect is very much a function of the diffusion process, which in turn depends upon the rate of adoption of innovative technologies. Therefore it is important for both the firms and policy makers to understand the rate of adoption of innovative technologies in order to evaluate the potential impact of technical change on the economy's overall productivity. Technology adoption has been the focus of an extensive literature.

## 2.3. Examples of Technology Adoption

There are many examples of the adoption of innovative technologies in the field of agriculture resulting in decreased production cost or increased revenue through higher yields. These include High Yielding Varieties (HYV), splash mulch technique, maize production in Northern Guinea, livestock technology adoption, and genetically modified crops.

A wide adoption of HYV (High Yielding Varieties) was one of the most significant changes in the Indian agriculture in recent decades (Zhang, Fan, and Cai, 2002). During the Green Revolution of the 1970's, the crop area planted with HYV's for five major crops (rice, wheat, sorghum, and pearl millet) increased from less than 17% in 1970 to 40% in 1980. It reached 44% of the crop area by 1985 and 53% by 1990(Zhang, Fan, and Cai, 2002). Even after the peak Green Revolution, the percentage of the crop area planted with HYV's continued to increase. It reached 59% by 1995. The annual growth rate of HYV adoption was at 9% in the 1970's, but it declined to 3% in the 1980's and further decreased to 2% in the first half of 1990's.

The role of high-yielding technologies in improving the standard of living of agricultural households in developing countries is also widely documented in economic literature. The article by Zhang, Fan, and Cai (2002) explained the diffusion process of High Yielding Varieties (HYV) technology and also provided the evidences for the increase in production due to the adoption of the technology. The authors have used a panel data set from 1970 to 1995 over 250 districts in India and applied a geographical information systems (GIS) program to investigate the regional neighborhood effect on the rate of diffusion of new technologies. The data were mostly from the Indian central and local governments. The results showed that the early successful adopters had more impact on the neighborhood farmers than the early unsuccessful adopters.

The evolution of maize production in the Northern Guinea Savanna of Nigeria where production systems evolved to higher productive systems and farmer welfare substantially increased, is another good example of technological breakthroughs (Smith et al., 1994). In this study the authors emphasized that, contrary to the conventional knowledge, 'quantum leap' technologies have a vital role to play in West Africa. While infrastructure such as a good transportation system and extension services were the preconditions for a positive outcome, the crucial element was the technological breakthrough that enabled farmers to achieve significant increase in income by expanding production of a crop in an area with ecological comparative advantage. Population was the major reason for the introduction of this agricultural development in West Africa in order to meet the food requirement of the growing population. There were only two possible ways: one was extensification (i.e., increase the area under cultivation) and the other was intensification (i.e., increase the intensity with which the same piece of land is cultivated). Between the two, extensification was ruled out because arable land was limited. The extent of additional inputs needed per unit of land depended on the returns to these extra inputs, which in turn were functions of input/output price ratio and the marginal product of each input. Further, the marginal product depended on the available technology and ecological conditions.

As a result of the adoption of improved maize, it was reported that maize which was a minor crop grown in the backyards in the mid-1970s became one of the three most important food crops by 1989, and it was also noticed that it became one of the most important cash crops in 70% of the sampled villages. Prior to this, the most important food crops were sorghum and millet, and the most important cash crops were cotton and groundnut. Almost all maize grown in 1989 was reported to contain improved germ plasma. It was observed that in the mid-1970s, only the local varieties were grown and after the adoption of improved maize 52% of the villagers claimed that the local varieties had disappeared (Smith et al., 1994). It was reported that over half of the villages adopted improved maize during the late 1970s, with adoption being the earliest in the Southern Katsina state. In the rest of the villages adoption occurred during the 1980s. The timing of the adoption process was confirmed by Balcet and Candler's (1981) study.

Slash mulch technique is another innovative technology that was widely adopted. It has been estimated that Central America's major share of forest area would disappear by the mid-21 century (Neil and Lee, 2001). The key factor responsible for this deforestation was identified to be the slash-and-burn agriculture in that region. This practice has not only reduced the forest area but also adversely affected the evapotransportation rate and rainfall, contributing to greenhouse gas emissions and threatening an important route for the North–South species interchange.

However it was not the slash-and-burn agriculture but improper land management that was causing the environmental damage. In fact, slash-and-burn technique improves soil quality, is good for weed management and ensures subsistence livelihood for resource-poor farmers if followed by a sufficient fallow period (Neil and Lee, 2001).

A few years after the introduction of the slash-and-burn technique, researchers have rediscovered new technology "slash mulch" agriculture as an alternative for slash-and-burn agriculture, which could ensure a better land management and was in accordance with the notion of sustainability. The new technology utilized legume velvet bean (a species of mucuna) and became very popular during the 1970's and 1980's. In this technique, legume velvet bean is planted as part of the maize rotation to reduce labor use, increase maize yields by adding to the biological phenomenon known as nitrogen fixation, and decreasing the use of fertilizers and pesticides, lowering production cost. Therefore, the maize-mucuna system enabled the farmers to improve their productivity on less land and reduced the need for slash-and-burn cultivation.

The widespread adoption of maize-mucuna system in Honduras was not only because of its economic and environmental benefits but also the spontaneous diffusion of this technique from farmer to farmer without any external intervention. However, the results of a study revealed that by 1997 the farmers were abandoning the maize-mucuna system at a rate exceeding 10% per year (Neill and Lee, 2001). The abandonment of maize-mucuna proved to be a complex phenomenon, which resulted from a wide range of factors such as tenure security, shifting land markets, the rise of extensive cattle raising, production orientation of farmers, and infrastructure development.

Most of the empirical studies on adoption and diffusion of high-yielding technologies focuses on the crop sector with few applications in the livestock sector. However, the livestock sector plays a significant role on the livelihood of many agricultural households in developing countries, particularly in sub-Saharan Africa. The contribution of livestock production in sub-Saharan Africa is about 25% of total agricultural output (Staal, Delgado, and Nicholson, 1997). Therefore, many governments and international agencies have invested in research and development in this sector. One such technology is crossbred cows (rather than common stock) that were developed to improve both milk and meat productivity. Despite, the higher productivity of crossbred compared to the traditional technology, its adoption rate was slow in sub-Saharan Africa (Staal, Delgado, and Nicholson, 1997).

**2.4. Paths of Technology Adoption**

The earlier studies emphasized the importance of farm size and credit constraints on the adoption process (Feder, 1980; Feder, Just, and Zilberman, 1985; Sunding and Zilberman, 1984). Some of the recent literatures have focused on the capacity of farmers to make decisions, learn the technology and the role of learning in the diffusion process (Foster and Rosenzweig, 1995a; Cameron, 1999; Conley and Udry, 2003). Cameron's (1999) work on rural Indian village emphasized the importance of learning-by-doing or-using. Conley and Udry (2003) examined the role of social learning for technology adoption by farmers in Ghana.

Economic investigations have typically made assumptions that relate observed relationships between individuals (such as geographical proximity) and unobserved but plausible inter-farm flows of information. This set of assumptions underlies all attempts to identify effects, which is clearly limited by available data.

There are several factors that could contribute to the observed pattern of geographical adoption of a new technology rather than just social learning. In the absence of data on direct learning effects, we assume that pressure from social emulation and localized competition encourages farmers to adopt new and profitable technologies. Baptistia and Swan (1998) demonstrated the geographical concentration of rivals encouraged competition and stimulated innovative activity, possibly leading to new entrants and firm growth.

In order to explain and analyze the path of technology adoption, the above mentioned authors have used two methodological frameworks namely an analytical framework and an empirical framework.

**2.4.1. Analytical Framework**

A complete analytical framework for the process of adoption should include a model of the farmer's decision making about the extent and intensity of use of the new technology at each point throughout the adoption process and a set of parameters that affect the farmer's decisions. The changes in these parameters occur due to the dynamic process such as information gathering, learning by doing or accumulating resources.

Maximization of expected utility (or expected profit) is the prime concern for a farmer based on which he makes his decisions in a given period of time. His maximization is subjected to factors such as land availability, credit and other resources (Feder, Just, and Zilberman, 1985). Profit is a function of farmer's choice of crop and technology in each time period. Therefore, profits depend on the selection of technology which is a mix including the traditional technology and the various components of the modern technology.

Under these circumstances of discrete choice the income of farmer is a function of the area of land under various crop varieties, the production function of these crop varieties, various inputs, price of the inputs and the outputs and the yearly cost associated with the technology applied. Given the chosen technology, land area and variable input values, perceived income is considered as a random variable subjected to objective uncertainties with respect to yields (and prices) and the subjective uncertainties related to the incomplete information about the production function parameters.

In many studies, the production function is assumed to be the only source of (objective and subjective) uncertainty to the farmer. A convenient and general specification of a production function assumes linearity in the random variable:

$$y = f(x) + g(x)\varepsilon$$

where, y denotes output, x is a vector of inputs and ε is a random variable with zero mean (Just and Pope, 1978). This kind of estimation is flexible because the model includes inputs (such as pesticides) which have a positive effect on the mean and but a negative effect on variance of the yield.

In most of the studies, farmer is assumed to have fixed land and operates each period, thus the farmer tries to maximize his utility subject to the land availability. The additional constraints that affect the farmer's decision are the availability of credit and the labor market. The solution for his optimization problems depends on the technology he uses during that period, the allocation of land to various crops and the variable input use. The yields, revenue and profits realized at the end of the year, experience gained during that period, and information from the neighboring farmers and other sources would update the farmer and thus help in the decision process for the next year.

There are several equations of motion that reflect changes in the decision-problem parameters over time, in the farmer's effectiveness with the new technologies. The changes may be due to learning-by-doing i.e., the farmers become more informed about the particular technology when they use it. Other reasons for these changes may be extension efforts and human capital (see Kislev and Shchon-Bachrach, 1973)

Another set of equations motion may reflect changes in prices and costs over time. In general, these equations emphasize the set up cost associated with the new technology. The technological improvement in the production of principal goods or in the marketing networks associated with the new technology may result in the changes in the cost and prices. Using these equations of motion the impact of the factors determining the technology choice of all individual over time can be addressed.

### 2.4.2. Empirical Framework

The theoretical studies reveal many hypotheses relating to the adoption of new technologies in the context of key economic and physical parameters, static and dynamic contexts, and micro and macro levels. The empirical studies help in interpreting the significance of the theoretical explanations. That is, the empirical works can confirm or reject the theoretical assumptions and also suggest the importance and new aspects of the conceptual framework (Feder, Just, and Zilberman, 1985). Empirical studies usually analyze the impact of the specific factors contributing to the given case. As this study focuses on the adoption of innovative technologies, the empirical studies dealing with the various factors affecting the process of technology adoption, are reviewed below.

## 2.5. Factors Affecting the Adoption Process

According to Ruttan (1977) the innovations are introduced in environments with different economic, socio and political institutions and therefore a huge amount of empirical literature on adoption is systematically based on key explanatory factors affecting the adoption process.

### 2.5.1. Farm Size

One of the important factors that have an impact on the empirical literature is farm size. Depending on the type of the technology and the institutional facilities, farm size has different effects on the rate of adoption. In particular, the relationship between farm size and adoption of technology is mostly influenced by factors such as fixed cost, risk preferences, human capital, credit constraints, and labor requirements.

Theoretical studies suggest that the technology to adopt and the rate of adoption by a small farm are influenced by the fixed cost of the implements. And this was supported by Weil's (1970) study in Africa, which revealed that the adoption of cultivation using oxen compared to hand cultivation served the purpose effectively in large areas. A study by Binswanger (1978) indicated a positive relationship between farm size and adoption of tractor power in South Asia. But it is important to know that this is not the same in every case as the relationship between farm size and adoption of technology depends on various designs and the emergence of markets for hired services (Staub and Blasé, 1974). Weil (1970) argued that a negative relationship between farm size and the adoption of technology could be attributed to credit constraints. That is, even though all the farmers might be interested in adopting the technologies, only the large farmers would most likely to pursue them.

In many of the empirical studies, it was found that a positive relationship exists between farm size and the adoption of technology. For example, Parthasarathy and Prasad (1978) found a positive relationship between HYV and farm size in a village in Andhra Pradesh, India during 1971 and 1972. Similarly, Jamison and Lau (1982, p. 208) also found a positive relationship between fertilizer adoption and farm size in a study of Thai farmers.

Opposing, there are studies which indicated a negative relationship between farm size and technology adoption. For example, Hayami (1981) cited evidence from the Barker and Herdt's (1978) study of 30 villages in five Asian countries. Many studies also supported the findings of Ruttan (1977) that the small farmers have greater adoption rate of HYV and also there are theoretical findings which say that the intensity of HYV adoption would be higher among the small farmers than among the large farmers. For example, Muthiah (1971), Schluter (1971) and Sharma (1973) found that the adoption of HYV by small farmers in India was proportionally higher than by large farmers. Vander Van (1975), who studied rice farming in the Philippines, also found a negative relationship between the adoption of modern inputs and farm size and gave three possible explanations for this phenomenon: (1) the farmers might be using the available land efficiently in order to fulfill their basic subsistence needs, (2) they may irrigate more efficiently, and (3) they may be using relatively low cost family labor. In some cases, the quality of land could also affect the relationship between the farm size and adoption of technology. For example, in the study of adoption of Green Revolution Technology, Burke (1979) found that the farmers with higher quality soil were more land intensive than their peers with lower quality soil, where land intensity was measured by a land-labor ratio.

Hategekimana and Trant (2002) examined the experience of the farmers in Ontario and Quebec who were the first to use Genetically Modified (GM) corn and soybeans. The statistical data for this study were gathered from Canadian Statistics Data from the 1996 Census of Agriculture and from the June Crops Survey for the years 2000 and 2001. The main findings of the study was that the probability of adopting GM crops on a farm was low if the farm size was large and if the ratio of the area seeded to soybeans or corn to total seeded field crop area is high. The authors found that in the initial years, the large farms were slower in adopting the GM crops than the small farms.

But, they paid attention to the success of the innovation and acted quickly to adopt at a greater rate. Thus, their overall findings supported the findings of Schumpeter (1942), Cochrane (1958), Reimund, Martin, and Moore (1981), and Cohen and Klepper (1996) that the large firms are the first to enjoy the benefits from innovations and adoption of new technologies.

In sum, most of the empirical results interpreted in the context of theoretical literature suggest that the relationship between farm size and adoption of technology is influenced by important factors such as credit constraints, access to scarce inputs (water, seeds, fertilizers, and insecticides), wealth, and access to information.

**2.5.2. Risk and Uncertainty**

Risks and uncertainties are also one of the important factors which hinder the adoption of innovative technologies. Primarily, risks are of two kinds: one is subjective risk (e.g. farmers believe yield is more uncertain with unfamiliar technology) and the other is objective risk (e.g. water variation, susceptibility to pests, and untimely availability of critical inputs, etc.). However, most of the empirical studies have rarely considered risks as they are difficult to measure. For example, Gerhart (1975) used drought resistant crops as a measure of risk in his study of maize adoption in Kenya and found it to be statistically significant in explaining the performance of adoption. However, his results were misleading as the choice of drought resistant crop is endogenous and should not have been included on the right hand side of the equation.

There have been attempts to account for risks appropriately. Some studies obtained observations from different climate and topographical areas, and using location-specific dummy variables, found their impacts to be significant (see e.g., Cutie, 1976).

But it was also noted that these dummy variables may also represent other factors, such as fertility (including rainfall, and soil quality) or access to markets. Binswanger (1978) obtained a measure for farmer's risk aversion for a sample of farmers in India through gambling experiments and used the measure as an explanatory variable in a multivariate analysis of fertilizer adoption with mixed results in terms of statistical significance.

The technology choice based on subjective risk is influenced by exposure to information regarding the new technology. For example, Gafsi and Roe (1979) found that Tunisia farmers' preference for the locally developed new varieties was higher than the preference for unfamiliar imported varieties. Most of the findings indicated that acquiring appropriate information from various communication sources would reduce the subjective uncertainties. But as usual there was a problem in measuring the extent of information that the farmers were exposed to. Another common variable was visiting with the extension agents (e.g., Gerhart, 1975) or attending demonstrations organized by extension services and other agencies (e.g., Demir, 1976; Perrin and Winkelmann, 1976). In general, no conclusion has been derived about the significance of information, because approximations by proxy variable were unreliable. For example, Vyas (1975) stated that literacy had nothing much to do with information if pilot programs were demonstrated and organized by the extension service. Most of the empirical studies have not accounted for subjective risk sufficiently to evaluate the theoretical predictions.

### 2.5.3. Human Capital

Unlike the subjective risk, the relationship between human capital and the adoption of innovative technologies has been well captured. According to Schultz (1964), frequent introduction of new technologies results in a state of disequilibrium with suboptimal use of inputs and the technology. He also suggested that work ability and allocative ability were human factors responsible for the returns from agriculture. Both abilities improve as experience and health improve. It has been hypothesized that education plays an important role in determining allocative ability, more so than determining working ability. This hypothesis has been supported by several studies. For example, Ram (1976) found that farmers' educational attainment was positively related to their production contribution. Sidhu (1974) found that farmers' education had greatly increased the gross sales of the farmers in the early stages of the Green Revolution in Punjab.

Welch (1970) hypothesized that the value of education increases with technological change. He also hypothesized that extension service is a substitute for education and the productivity of education is enhanced by the size of the farm and he verified these hypotheses in study of wage patterns of American farmers with different educational levels and its response to productivity.

Several studies have investigated the effects of education on dynamic adjustment to changes in prices. For example, Huffman (1977) found that the farmers with higher education adjusted their use of nitrogen in response to changes in its price than less educated farmers and their input levels also reached the optimum very quickly when compared to the less educated farmers. Another good example for this is the dynamics of adoption and diffusion of an innovation in rural Ethiopia (Weir and Knight, 2000). Education was distinguished as formal, nonformal, and informal. All the three forms of education were important for the process of adoption and diffusion of innovations. The educated farmers were the initiators in the process of adoption of innovations, either introducing new ideas themselves or being the first to copy a successful innovation. Moreover the agricultural extension workers most likely targeted educated farmers for nonformal education.

Foster and Rosenzweig (1995b) tested the importance of learning in adoption using three-year panel data from 25 villages in India. The results concluded that learning from own experiences and learning from neighbors' experiences were both determinants of adoption. The finding that learning is an important determinant of adoption was in contrast to the earlier work by McGuirk and Mundlak (1992) which suggested that adoption was constrained by the insufficient access to irrigation and fertilizer, not by insufficient information. Evidence of the importance of learning in the adoption of innovative technologies in the farming sector provides support for policy initiatives such as the educational support facilities for the technologies.

Nelson and Phelps (1996) modeled diffusion of technological innovations in terms of the gap between actual and possible levels of technology and the amount of education of the work force. The results revealed that returns to education were greater when there were more opportunities for adoption of technology innovation. Since there are externalities to innovation, if education stimulates innovation, there are externalities to schooling.

However, in developing countries the applied literature on the effect of education on the process of adoption and learning externalities is limited. Jamison and Moock (1984) tested the effect of schooling and extension contacts on the process of adoption and diffusion of agricultural innovations in Nepal and found that schooling influenced the adoptive behavior. They also found that in the process of adoption and diffusion of innovative technologies in agriculture the individual extension contacts were less important than extension activities. Cotlear (1986) used a rural household survey covering three regions in the Peruvian Sierra and found that education played a significant role for the early adopters and that the late adopters simply copied their neighbors behavior, in using education to decrease the cost in accruing information and learning the application of innovative techniques. To measure learning spillovers, Foster and Rosenzweig (1995a) found, using panel data on rural households affected by the Green Revolution in India, that farmers with experienced neighbors (i.e., neighbors who have already adopted the technology) were more profitable than those without such neighbors. A study by Croppenstedt, Demeke, and Meschi (2003) using data from 1994 U.S. Agency for International Development fertilizer marketing survey, finds that literate farmers were more likely to adopt use of fertilizers than those who are illiterate.

From the above studies it was found that the farmers with more education were the first to adopt an innovative technology and also apply modern inputs efficiently throughout the adoption process. Several empirical studies have also proved this relationship between education and early adoption and some of the evidences were provided by Evenson (1974) and Villaume (1977). In some studies panel data and discrete choice models were used to capture the effect of human capital on adoption. Gerhart (1975) found a positive relation between the likelihood of adoption and education in the hybrid maize case in Kenya. Rosenzweig (1978) found that education and farm size had a positive effect on the adoption of high yield grains in Punjab.

### 2.5.4. Social Learning

The process of "social learning" has motivated much of the work existing on the adoption of innovative technologies in the farming sector (Besley and Case, 1993; Foster and Rosenzweig, 1995a) and there have been many ways of thinking about this social learning in the process of technology adoption. For example, consider a social group (village) engaged in a process of collective experimentation and each farmer observes one another including those who are experimenting with the innovative technologies. And accordingly each farmer revises his or her opinion regarding the innovative technology and tries to implement it in the coming season, and the learning process continues. Two important assumptions are considered in the process of social learning: first that each farmer sees the information based on the outcome of each farmer in the village, and second that each farmer observes other farmers experiment without any information loss. Burger, Collier, and Gunning (1993) argue that in Kenya social learning takes place in agriculture, with economic agents placing weight on the choices of others who are similar to themselves.

An example of social learning took place in the part of Ghana's Eastern region where an established system of maize and cassava intercropping for sale to urban consumers was replaced by intensive production of pineapple for export to European countries. In this transformation the component to be noticed was the adoption of agricultural chemicals that were not used in the past farming system.

### 2.5.5. Information Sources

According to the human capital theory, innovation ability is closely related to education level, experience and information accumulation, i.e. those characteristics associated with the resource allocation skills of farm operators (Schultz, 1972; Huffman, 1977; Rahm and Huffman, 1984). It is expected that the gathering of information, irrespective of the technology itself, improves resource allocation skills and also increases the efficiency of adoption decisions.

There are many possible sources of information about the new technology (Rogers, 1962). A farmer may learn from his or her own experimentation with the technologies. The extension services or the media will provide advice and the necessary information regarding the innovative technologies, aiding in learning the pros and cons of the innovative technologies while leaving the decision to the farmer whether to adopt the technology. And if there are many farmers in the same situation then the learning process becomes social. Farmers can also learn about the characteristics of the innovative technologies in the farming system from their neighbors' experiments.

The farmers gather information from various sources. As the degree of reliability of the available information increases with cost, the producer's decision to gather information becomes complicated (Kihlstrom, 1976). In the process of the adoption decision, the determinants of the innovation adoption vary from the source of information it has been disseminated (Wozniak, 1993; Gervais, Lambert and Boutin-Dufrense, 2001). In this context, the information sources are distinguished as "active sources" and "passive sources" (Feder and Slade, 1984). The information incidentally acquired by the farmers from sources such as newspapers, television, radio, agricultural fairs and events, seminars, meetings and demonstrations are referred to as active sources information. The information regarding farming acquired by the farmers through periodical contacts with public or private extension agents is referred to as the passive source information.

### 2.5.6. Labor Availability

Another important variable affecting the farmers' decision choice in adopting an innovative technology is labor availability. Some of the innovative technologies are labor saving and some are labor consuming. For example, ox cultivation is a labor saving technique (compared to hand cultivation) and whereas the HYV technology requires more labor, and therefore labor shortage may hinder adopting the technology.

One of the main reasons for mechanization in agriculture has been to eliminate the labor scarcity problem. For example, ox power and tractor power ensure timely farm operations, increased production and decrease the labor demand. These arguments were confirmed by Weil (1970) in Gambia, Aliviar (1972) in Laguna, and Spenser and Byerlee (1976) in Sierra Leone. The results of these studies were in accordance with the theoretical work and suggest that uncertainty in labor availability can be explained by adopting new labor saving technology.

Hicks and Johnson (1974) studied the adoption of labor-intensive varieties in Taiwan and found that labor supply has a positive impact on adoption. Similarly, Harriss (1972) found that the shortage of labor supply was the reason for non-adoption of HYV's of cereal crops in India.

In some cases new technology will increase the seasonal demand for labor and therefore it is not approached by those having limited family labor and also those operating places which have less access to labor market. The peak-season labor scarcity was a major constraint in African farming system (see e.g. Helleinger, 1975). However, this problem of peak-season labor scarcity can be solved if the neighboring regions have a different peak time and temporary migration of labor is allowed.

### 2.5.7. Credit Constraints

Most of the theoretical studies argue that the fixed investment costs prevent small farmers from adopting new technologies. Capital in any form (saving or capital markets) is essential to finance a new technology. Thus, the credit constraint is considered as one of the important factors that influence adoption of innovative technologies. These implications were confirmed by the descriptive and empirical work on credit (e.g. Lowdermilk, 1972; Lipton, 1976; and Bhalla, 1979).

Many studies have found that lack of credit played a significant role in the adoption of HYV technology which did not involve huge fixed costs. For instance, Bhalla (1979) in a study found that different farmers have different reasons for not using fertilizers in 1970 and 1971 and lack of credit was a major constraint. The results showed that credit was a constraint for 48% of small farms and only 6% of the large farms. The author concluded that “access to credit may be responsible for the gain in income (and HYV area) made by the large farmers” (Bhalla, 1979, p.143). Similarly, many studies have also found that for small farms, the credit constraint was the primary reason for not adopting divisible technologies such as fertilizer use (e.g. Frankel, 1971; Wills, 1972; Khan, 1975). Subsidization policies had been assumed to be a solution to minimize the discouraging effect of the credit scarcity. But, Lipton (1976) disagreed with this because most of the time, large shares of the credit go into the hands of large and influential farmers and not the needy small farmers. Further, restrictions on input use (e.g., lower limits on fertilizer and pesticides applications) would hinder the adoption regardless of what the access to credit might be (Scobie and Franklin, 1977).

## 2.6. No-tillage Systems

### 2.6.1. Introduction

Soil quality plays an important role in agriculture as the crop yields are directly related to the soil quality such as the nutrient content, organic matter content, water holding capacity, and soil texture. The depth of the topsoil and the water holding capacity of the soil are greatly reduced by soil erosion caused by wind or rainfall. The intensity of soil erosion depends on soil type, climate, topography, and farming practices among others. Soil erosion leads to reduced crop yields. It is difficult to measure reductions in yields due to soil erosion because it is not the only factor on which the crop yield depends. Other factors, like the technology used to improve the fertility, amount of fertilizer used over time, and improved crop varieties also play a great role in crop yields. Nonetheless, if the rate of soil erosion exceeds the rate of soil formation, then the long-term productivity of soil would be greatly reduced.

Using additional fertilizers is not the solution for soil erosion which causes reduction in the depth of the top soil and reduces the water holding capacity of the soil, thereby decreasing the crop yields. Rather, using appropriate technology and good soil management practices might be a good alternative for farmers to reduce soil erosion. They might choose suitable crops, plant cover crops, change crop rotations, construct terraces, or use conservation tillage methods (Batie, 1984).

There are different tillage systems, but they are broadly classified into two: the conventional tillage (CT) system and the conservation tillage systems. CT may be referred as to a cultivation practice which includes moldboard ploughing and seedbed tillage before drilling, while the conservation tillage may be referred to as a practice which incorporates both the fertilizer and the seed together into the soil directly through the residues of the previous crop (Lankoski et al., 2006). The CT system is known to be prone to soil erosion, whereas the conservation tillage systems conserve and preserve the soil. As said above, it is not only the conventional tillage system but also the poor soil management by most of the farmers that severely degrades the soil.

The adoption of conservation tillage differs across regions, crops, and topographies, among others. Conservation tillage is defined as a cultivation practice that decreases the disturbance of soil structure, composition and natural bio-diversity and hence reduces soil erosion, degradation and contamination (Anonymous, 2001). The combination of no-tillage and residue management and cover crop management will maintain the quality of the surface water. There has been a widespread use of no-till and other conservation tillage technologies in North and South America and Australia, and the techniques also have been considerably increasing in tropical regions (Lal, 2000). In the USA and Canada, no-tillage covers 37 percent of the total area under cultivation and in South America no-tillage covers 48 percent (Holland, 2004).

The no-tillage (NT) system is considered as one of the conservation tillage methods. The development and adoption of no-tillage system led to a more sustainable cropping system (Carter, 1994). The adoption of no-tillage system, along with cover crops and crop rotation, greatly reduces soil erosion, controls weeds, and thereby improves soil productivity. For example, the no-tillage production system reduced soil loss by 95 to 99 percent on Brown Loam soils in Mississippi (Triplett et al., 1997). Triplett, Landry, and Amara (1996) also found that during the period 1988-1992 the average yields of no-tillage cotton was 36 percent greater than the yields of conventional tillage cotton. Several studies on cotton provide evidence that no-tillage cotton yielded equally to or more than those of conventionally tilled cotton (Stevens et al., 1992; Triplett, Landry, and Amara, 1996).

The remainder of this section provides the various concepts related to soil erosion and gives an overview of the previous research conducted on the economics of no-tillage, soil erosion, and crop management practices, factors involved in the adoption of conservation tillage, compares no-tillage system with other tillage systems, and factors effecting the conversion of CT to NT.

**2.6.2. Soil Erosion and Productivity of Soil – Related Physical Factors**

One of the prime concerns for agricultural production is the loss of topsoil. The loss of topsoil greatly reduces the available nutrients to the plant and also decreases the organic matter content of the soil. As soon as the first rain drop falls on the soil, erosion starts. The rate of erosion depends on the intensity and the duration of the rain as it breaks the soil granules and separates them into individual particles. The flow of the rain water on the soil surface carrying away the suspended soil particles results in sheet erosion. As the rate of water flow increases, the water gets accumulated into small channels called rills. Later these rills enlarge and transform into gullies and destroy the soil productivity (Clark, Haverkemp, and Chapman, 1985). Prolonged drought areas are very much prone to considerable soil loss due to wind erosion (Batie, 1984).

There are several other factors which cause soil erosion such as vegetative cover, land slope, soil type, contour farming, and terrace construction. In general the soil is covered by crop vegetation and if this is removed by over grazing or fire, then there will be many changes to the soil. Vegetative cover will effectively prevent wind erosion.

Slope of the land also plays an important role in soil erosion. As the slope of the soil increases, the rate of erosion increases due to wind and water depending on the intensity of the wind and runoff water. Different soils have different levels of resistance to erosion. The resistance level depends on the composition of the soil such as texture and clay content, amount of organic matter, and soil depth. Generally granular and crumby soils are considered to be stable and well structured soils. Therefore, well structured and stable soil have good resistance and prevent the separation of soil particles, have good water absorbing capacity, and thus reduced the amount of runoff. Contour farming combined with vegetative covers is a good practice to prevent erosion. In contour farming the rows are planted at a right angle to the slope of the farm. Constructing terraces is another good practice in sloping areas to prevent soil erosion because they divide the area into small regions and protect a certain area above it as they reduce the speed of the runoff. Moreover water collected at each terrace is let out through a specific channel and thereby reduces the loss.

The annual soil through sheet or rill erosion can be estimated through the Universal Soil Loss Equation (USLE). The USLE is (Lal, 1994):

$$A = R*K*(LS)*C*P \tag{1}$$

where A = Soil loss (tons per acre per year); R = Rainfall factor; K = Soil erodibility factor, erosion rate per unit of R for a specific soil; LS = slope length and steepness factor (considered together); C = Crop management factor, i.e., the ratio of soil loss from a field with specific cropping and management to that from the fallow condition on which the factor K is evaluated; and P = erosion-control practice factor, ratio of soil loss with contouring, strip cropping, or terracing to that with straight-row farming, up and down the slope. The USLE illustrates that apart from climate and soil type, which is a physical feature of the soil, soil erosion depends on the management and cultural practices used, which are highly influential and very difficult to evaluate (Hudson, 1971).

No-tillage and residue management have considerable environmental benefits like reducing soil erosion, nitrogen run-off, and particulate phosphorus run-off (Soileau et al., 1994; Stonehouse, 1997). However, not all the environmental benefits are favorable for crop production and few problems have been identified. First, certain studies report that due to the accumulation of phosphorus in soil surface, the dissolved phosphorus run-off may increase (McIssac, Michell, and Hirschi, 1995; Holland, 2004). Second, no-till decreases the surface water run-off, and leaching to ground water increases (Holland, 2004; Wu et al., 2004). Third, initially no-tillage lowers herbicide run-off (e.g. sediment – bound active ingredients), increases weed and therefore requires high rate of herbicides, thus, this eventually in the long run increases the herbicide run-off (Sturs, Carter, and Johnston, 1997; Tebrugge and During, 1999; Fuglie, 1999).

There are other practices to be kept in mind to make the adoption of conservation tillage system a success, which include conserving residues to the maximum, growing crops which produce fewer residues with other crops, and growing crops susceptible to high residues. The two major crops which achieved great success when grown in rotation and adopting conservation tillage system are soybeans and corn. Crop rotation is one good practice which prevents both water and wind erosion.

#### 2.6.3. Factors Involved in Adoption of Conservation Tillage

Conservation tillage methods varies across soil quality and by the number of times soil tillage is applied. Optimum conservation can be defined as the usage rate over time which results in the possible present value for the expected net returns in the future (Buse and Bromely, 1975). Present value can be defined as the today's value of an asset expecting to arise in the future. For example, the present value for an annual discount rate of 15% on $115 in a year's time is $100.

The technique of discounting of cash flows to their net present values (NPV) contributes to economically efficient decision. Therefore we can compare the different tillage systems by observing the patterns of their cash flow and returns in the future. NPV of a project is calculated as the difference between the sum of the future cash flows discounted at a particular rate and the initial investment cost. NPV directly includes the time value of money and moreover it is not sensitive to mixed investment cash flows (Bussey, 1978). Under certainty, the NPV for a particular planning region can be calculated if the values of all the variables are known. If the NPV is positive it means to say that the project is expected to be beneficial and if the NPV is negative then the project is expected to be non-beneficial.

In order to tackle the uncertainties there are two approaches, simple risk adjustment and probability adjustment (Ansell, Bennett, and Bull, 1992). Simple risk adjustment is the application of safeguard condition on financial evaluation (e.g., making conservative cash flow estimate) or compensating with a determined risk premium (e.g., increasing the discount rate). This method alone does not explicitly measure the risk involved. The probability distribution requires estimation of the uncertainty in cash flows and then it derives the probability distribution of variables such as NPV.

Earlier economic analyses indicated that the adoption of conservation tillage system was lower for small farms (Lee and Stewart, 1985; Rahm and Huffman, 1984) and farmers with less education (Rahm and Huffman, 1984). Other economic studies indicate that adjustment costs (cost of new machinery and learning how to use technology in order to obtain high yields) from conventional tillage to conservation tillage might also be one of the reasons for slow adoption (Krause and Black, 1995)

Lee and Stewart (1985) suggested that the adjustment cost associated with machinery investment hinders the adoption of conservational tillage practices among the small farmers. Nowak and Korsching (1985) showed that a positive relation exists between education and quality of crop residues, and a learning curve exists for conservation tillage adoption.

**2.6.4. No-tillage System Versus Other Tillage Systems**

The profitability of a production system depends on the duration of the venture, whether it short term or long term. Usually for long term benefits we need to follow economically feasible practices. In the case of no-tillage, it is advantageous when the long-term equipment cost and the depreciation are considered in the analysis. But it is not preferable in the short run due to high costs of herbicides. Generally farmers have a limited source of capital and therefore they adopt a system which involves low cost and have short term returns (Carter, 1994).

For example, the study conducted by Harman, Michels, and Wiese in 1989, where they analyzed the profitability of no-tillage cotton production in the central Texas high plains found that no-tillage yields were higher than the conventional tillage every year, averaging a 41 percent (110 kilogram per hectare) increase over the 4-year study period. But in the initial stages the herbicide costs for no-tillage was very high ($167 per acre) when compared with that of conventional tillage ($12 per acre). Also the return above variable cost was higher for conventional tillage (on average $32). However, in the long run no-tillage gained more net returns as it reduced the equipment cost and depreciation and increased the deficiency payments, which were attributed to the increased yields from no-tillage.

Similarly, Phillips et al. (1980) conducted a study where they evaluated three different kinds of tillage systems including no-till (NT), chisel plow (CP) and moldboard plow (MP) tillage systems initiated in the year 1989 at the University of Illinois Dixon Springs Agricultural Research Center. The objective of this research was to measure crop yields, estimate equipment and machinery cost and compare the net returns from NT, CP, and MP tillage systems. It was found that the yields in the first 2 years were less for the NT system compared to the MP system, but were higher for the last 4 years. The NT system involved low machinery cost and required less labor force and thus generated higher net returns with lower labor management when compared with the MP system which involved highest machinery and labor requirements. However, higher herbicides rates were required for the NT system. On an average during the 6-years study the NT system had $32 higher net returns and the CP tillage system had $8 higher net returns when compared with MP tillage system. Moreover, the soil losses for the MP, CP, and NT systems were 13.5, 7.3, and 3.9 tons per acre per year respectively. Thus, the results indicated that the NT system is most profitable with highest net income over time due to reduction in soil loss from erosion.

Triplett, Dabney, and Siefker (1996) also compared different tillage systems. During the first year of the study, crops such as cotton, grain sorghum, and soybeans, and a wheat-soybean double crop system were planted involving under CT, NT, and two other reduced-tillage systems on grassland in Tate County, Mississippi. In 1993, corn was substituted for sorghum and reduced tillage was switched to no-tillage. It was observed that in the first 2 years the NT system had lower yields of cotton and also delayed the maturity compared to the CT system. But, during the third and fifth years the NT system yielded 18-42 percent greater than the CT system and also the maturity was 6-10 days earlier in the NT system compared to the CT system.

Triplett et al. (1997) compared the profitability of CT and NT for different crops during the years through 1995. The authors included capital and interest inputs, equipment and labor costs in their analysis. It was found that the average cotton lint yield for the CT and NT systems were 618 and 828 kilograms per hectare respectively, and the net returns were $319 and $437 per hectare respectively. The results of the study indicated NT cotton was feasible for annual cropping without compromising profitability and moreover protected soil productivity from soil erosion.

**2.6.5. Factors Affecting the Conversion of CT to NT**

The choice between the conservation tillage system and conventional tillage system depends on the farmer's choice whether to incur costs now or in the future (Batie, 1984). Stults and Strohbehn (1987) conducted an experiment to estimate the on farm productivity benefits and offsite damage reduction benefits of erosion control. He used the present value (PV) technique to estimate the benefits. The estimated PV of adopting the conservation tillage for 50 years at 12 percent (private discount rate) was $10.52 per hectare and at 4 percent (social discount rate), it was $46.60. It implies that society would gain $ 46.60 per hectare if the farmer adopted the practice for 50 years. And thus the trade off for the public will be $36.08 net benefit by paying the farmer $10.52 to adopt erosion control practices. Thus the study suggested that there will be a net benefit if assistance is provided on the basis of economic benefits and costs to adopt erosion control practices.

### 2.7. Unanswered Questions

In the collective understanding of innovative technology adoption in the agricultural sector, many questions remain unanswered. For instance, to what extent are socially valuable technologies slow to realize their potential due to information constraints or to externalities that lead the private and social value of new technologies to diverge? Before answering this question it is necessary to conduct a thorough analysis on the technology adoption decision by the farmers. The major concern for economic research on technology adoption is the question as to what determines the decision of the farmer to adopt or reject an innovation. However, as said earlier the gathering of information on the new technology is not sufficient but also the farming practices in general also determine his or her decision to adopt an innovation.

# Chapter 3: Data

## 3.1. Survey

The data for this study were taken from a database of survey responses, which were collected from farmers who participated in different workshops and conferences throughout the state of Kansas (Peterson et al., 2007). The survey was conducted at four different events between August 2006 and January 2007. The Risk and Profit Conference (Manhattan, KS), Kansas Farm Bureau Conference (Wichita, KS), Sunflower Agricultural Profitability Conference (Smith Center, KS), and Post Rock Agricultural Profitability Conference (Colby, KS).

A total of 135 respondents participated in the survey. The participants were registered through pre-registration mailing and an announcement at the opening of the conference. The survey was a one-hour parallel session during the conference. As mentioned in the pre-registration mailing and at the opening session of the conference each participant was given an incentive of $50 in cash to encourage participation. The data collection procedures were pre-tested with a small group (12) of producers from the Great Plains.

As a part of the session, the participants were shown a brief presentation on Water Quality Trading followed by the instructions to complete the survey. Then, a question and answer period was held to clarify any questions, and the participants filled out a booklet with 16 choice sets. After completion of the booklet the participants filled out a questionnaire with information regarding to his/her farm operations, his/her attitudes towards water quality issues and policies, and demographic data.

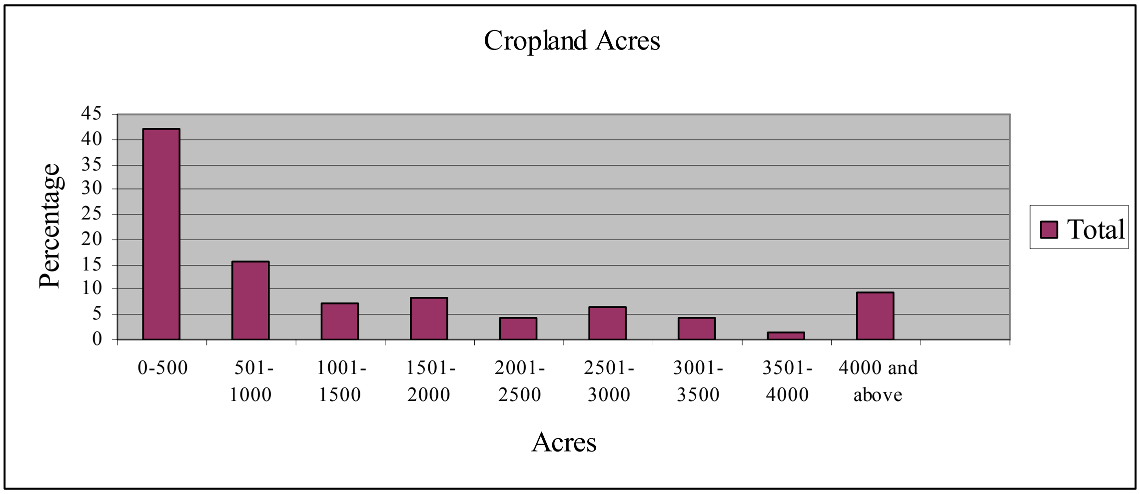
Detailed information was gathered about their cropland acreage, their perceptions of environmental damage on their farms, demographic characteristics, their familiarity and participation in various conservation programs, best management practice that describes their current farming operation, their primary occupation, and their membership in the Kansas Farm Management Association (KFMA).

KFMA is one of the largest farm programs in the United States. The objective of KFMA is to provide all its members with information that would be helpful in making there farms and family decisions through on-farm visits, whole-farm analysis, enterprise analysis, and other educational programs. The executive staff of KFMA is composed of twenty association economists, who assist the members in improving their farm accounting systems, improving decision making, performance evaluation of similar farms, and assist in investment plans through integration of tax planning and marketing.

**3.2. Farm Characteristics**

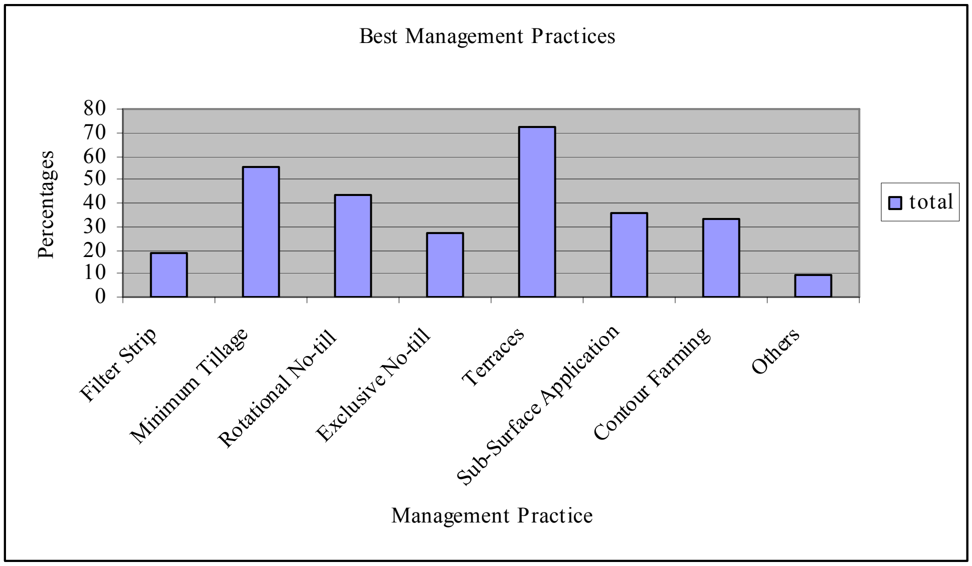
The average farm size for the 135 survey participants was 1628.7 acres (owned – 824.4 and rented – 804.4). About, 42.2 percent of the respondents operated less than 500 acres of cropland, 15.6 percent of the respondents operated on cropland acreage ranging from 501 to 1,000 acres, 7.4 percent of the respondents operated on cropland acreage ranging from 1,001 to 1,500 acres, 8.2 percent of the respondents operated on cropland acreage ranging from 1,501 to 2,000 acres and the remaining worked on cropland acreage ranging from 2.001 to 15,000 acres. As a reference, based on the 2002 Census of Agriculture 78.8 percent of the farmers had less than 1,000 acres of cropland and the remaining 21.2 percent had cropland greater than 1000 acres in Kansas (USDA-NASS). The detailed information regarding the cropland acreage is summarized in figure 1.

**Figure 1 – Cropland Acres**



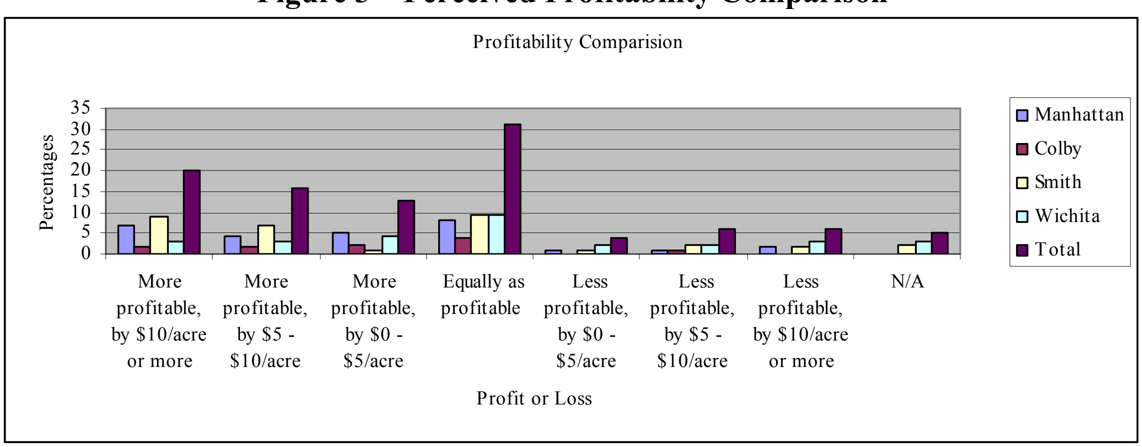

The respondents were asked to identify all best management practices they currently used in their farming operations. In addition to minimum tillage, rotational no-till and exclusive no-till, the other management practices followed were terraces, sub-surface application, contour farming and filter strips. Terrace referred to a soil conservation management practice where the hilly cultivable land is leveled into sections giving a stepped appearance, preventing surface runoff. Seventy-two percent answered using terraces, compared to 55 percent minimum tillage, 43 percent rotational no-till, 36 percent sub-surface application, 33 percent contour farming, and 27 percent exclusive no-till. The details regarding their best management practice is summarized in figure 2.

**Figure 2 – Best Management Practices**




Regarding the profitability of the no-till system relative to the other tillage systems, 42 ( 31 percent) farmers said that no-till was equally profitable, 27 (20 percent) respondents believed that no-till was more profitable by $10 or more per acre, 21 (15.6 percent) respondents believed that no-till was more profitable by $5 - $10 per acre, and 17 (12.6 percent) respondents believed that no-till was more profitable by $0 - $5 per acre. Only 21 (15.6 percent) found it to be less profitable than other tillage systems. The details about profitability comparison between no-till and other tillage systems are summarized in figure 3.

**Figure 3 – Perceived Profitability Comparison**

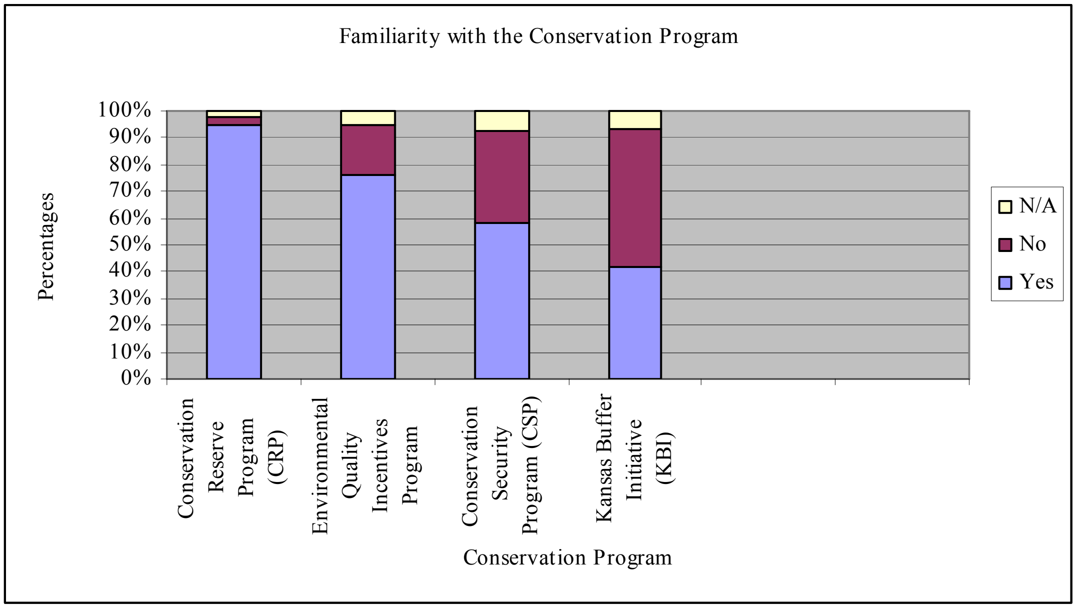


The survey participants were also asked about the familiarity of and participation in four major conservation programs available to them in Kansas, which included the Conservation Reserve Program (CRP) and the Environment Quality Incentives Program (EQIP), explained in Chapter 1, along with the Conservation Security Program (CSP) and the Kansas Buffer Initiative.

The CSP was authorized by the Farm Security and Rural Investment Act 2002. Similar to the CRP and EQIP this program is also administered by the NRCS to provide financial and technical assistance to promote the conservation and improvement of natural resources, plants and animal life on tribal and working lands (croplands, grasslands, prairie land, improved pasture, range land, and forested land operated for agriculture purpose). The Kansas Buffer Initiative program is administered by the State Conservation Commission (SCC), aiming to enhance the participation of CRP program for the installation of forest buffers and grass filter strips.

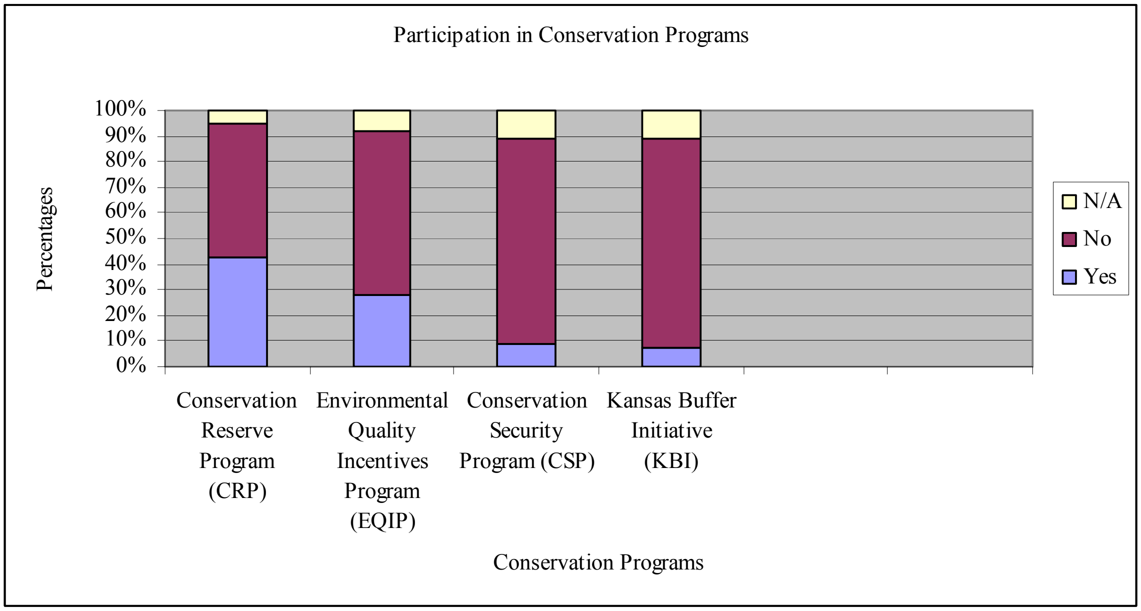
Ninty-five percent of the respondents were familiar with the CRP, as compared to 76 percent with the EQIP, 58.5 percent with the CSP, and 41.5 percent with the Kansas Buffer Initiative. The familiarity with the conservation programs is summarized in figure 4.

**Figure 4 – Familiarity with the Conservation Program**




Roughly, 43 percent participated in the CRP, 28 percent participated in the EQIP, 9 percent participated in the CSP, and 7.5 percent participated in the Kansas Buffer Initiative program. The details about their participation in various conservation programs are summarized figure 5.

**Figure 5 – Participation in the Conservation Program**



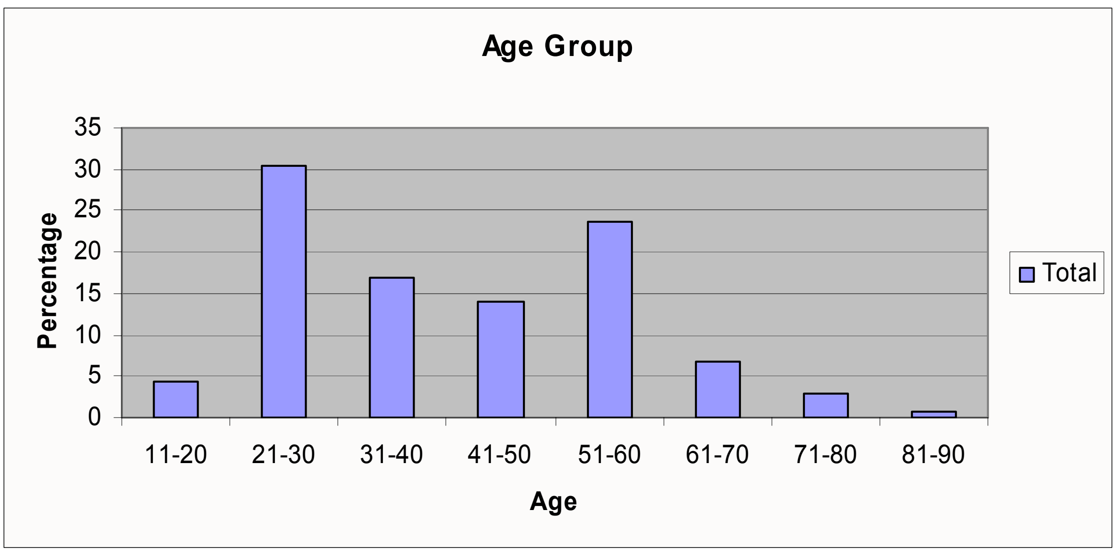

### 3.3. Operator Characteristics

About 80 percent of the farmers were males, 19 percent were females, and the rest did not answer. This was similar to the male farmers' percentage of 91 and female farmers percentage of 9 based on the 2002 Census of Agriculture (USDA-NASS). The details of gender are summarized in figure 6.

**Figure 6 – Gender Comparison**

The farmers were classified into age groups of 11-20 years through 81-90 years. About 30 percent belonged to the age group 21-30 years, 24 percent belonged to 51-60 years, 17 percent belonged to age group 31-40 years, and the remaining 29 percent belonged to other different age groups. The average age of the farmers is 41.5 and which is younger than the farm operators' average of 56 years of age based on the 2002 Census of Agriculture (USDA-NASS, 2004). The details about age groups are illustrated in figure 7.

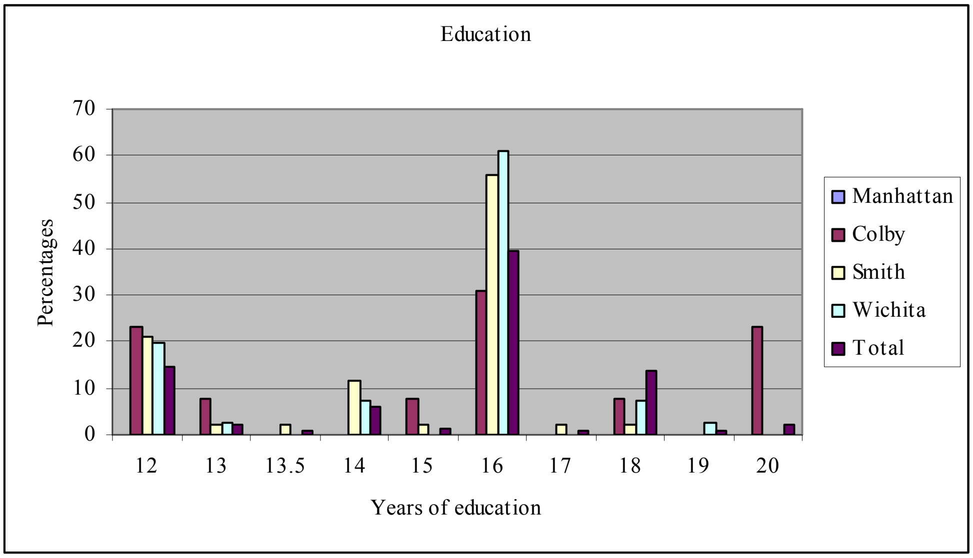
**Figure 7 – Age Group Comparison**




Roughly, 39 percent of farmers were college graduates (16 years of education) as compared to 15 percent being high school graduates (12 years), 6 percent having 14 years of formal education, and 4 percent having 18 years of formal education. These figures can be compared to the national figures based on 2006 Agricultural Resource Management Survey and the U.S. Department of Commerce, Bureau of Census, with 10.2 percent with less than high school, 41.7 percent being high school graduates, 23.1 percent being from college, and 25.0 percent being college graduates and beyond

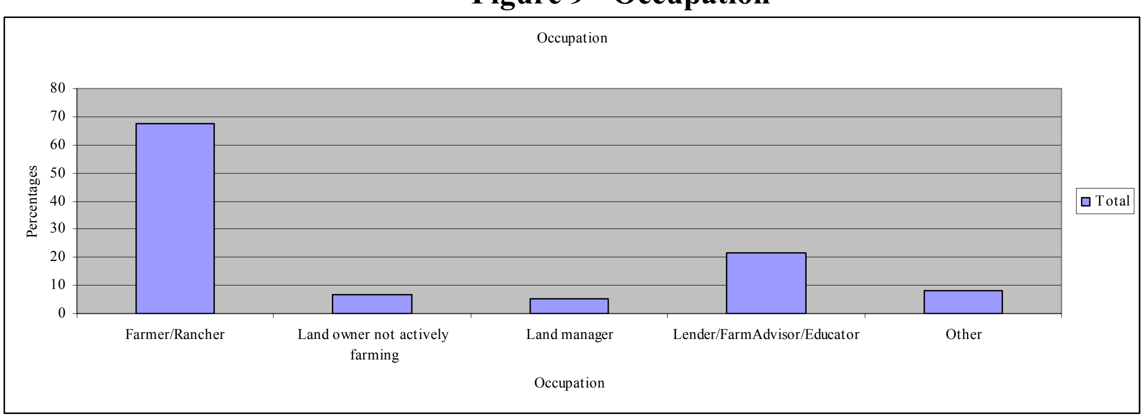
(USDA-ERS, 2008). The detailed information regarding their formal education is summarized in figure 8.

**Figure 8 – Education Comparison**



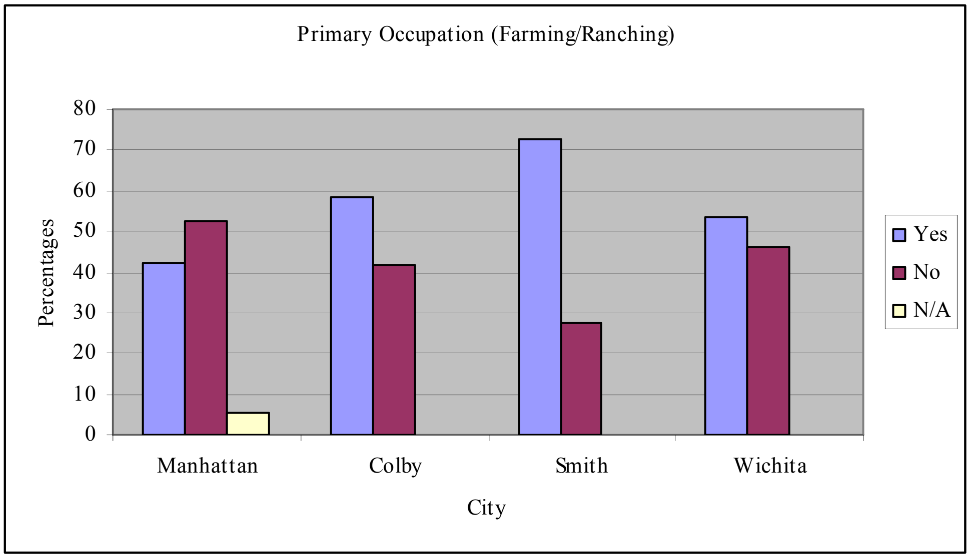

About 91 farmers (67.4 percent) described their primary occupation as farmer or rancher as compared to 29 (21.5 percent) described their occupation as land manager, and 11 (8.1 percent) described as lender or farm advisor or educator. The responses regarding their occupation are illustrated in figure 9.

**Figure 9 - Occupation**



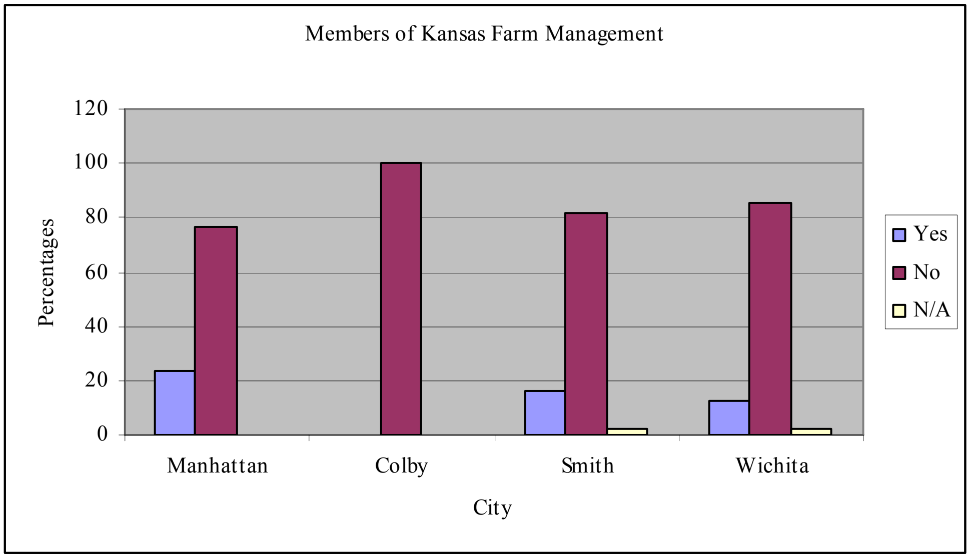
When asked about their primary occupation 57 percent of the respondents answered farming or ranching as their primary occupation and 2 percent did not answer. The details regarding their primary occupation is summarized in figure 10.

**Figure 10 – Primary Occupation (Farming/Ranching)**



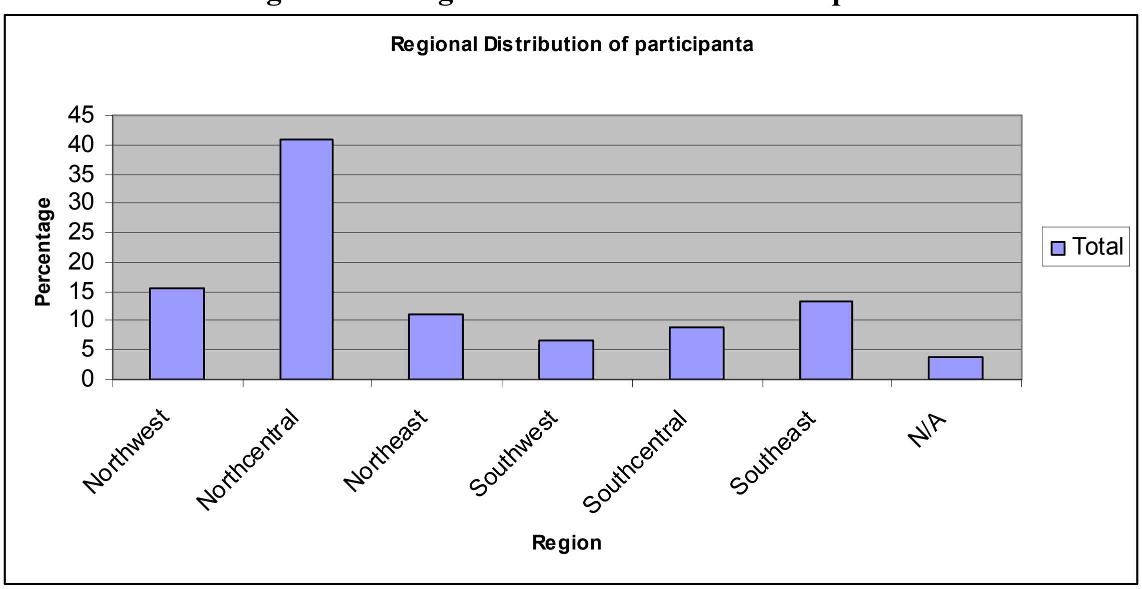

Roughly, 16 percent of the respondents were members of the Kansas Farm Management Association as compared to 83 percent who were not, and 1 percent did not answer. The responses are illustrated in figure 11.

**Figure 11 – Members of Kansas Farm Management**



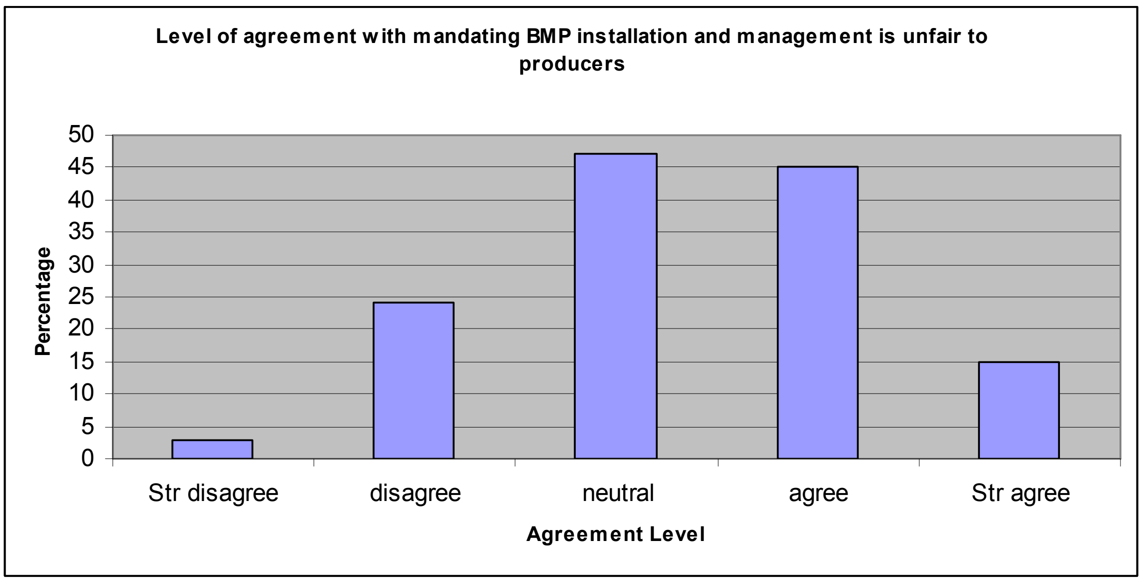

Within the state of Kansas, 16 percent of the respondents belonged to the northwest region, 41 percent belonged to the north central region, 11 percent belonged to the northeast, 7 percent belonged to the southwest, 9 percent belonged to the south central, and 3.5 percent belonged to southeast region. The responses are illustrated in figure 12.

**Figure 12 – Regional Distribution of Participants**



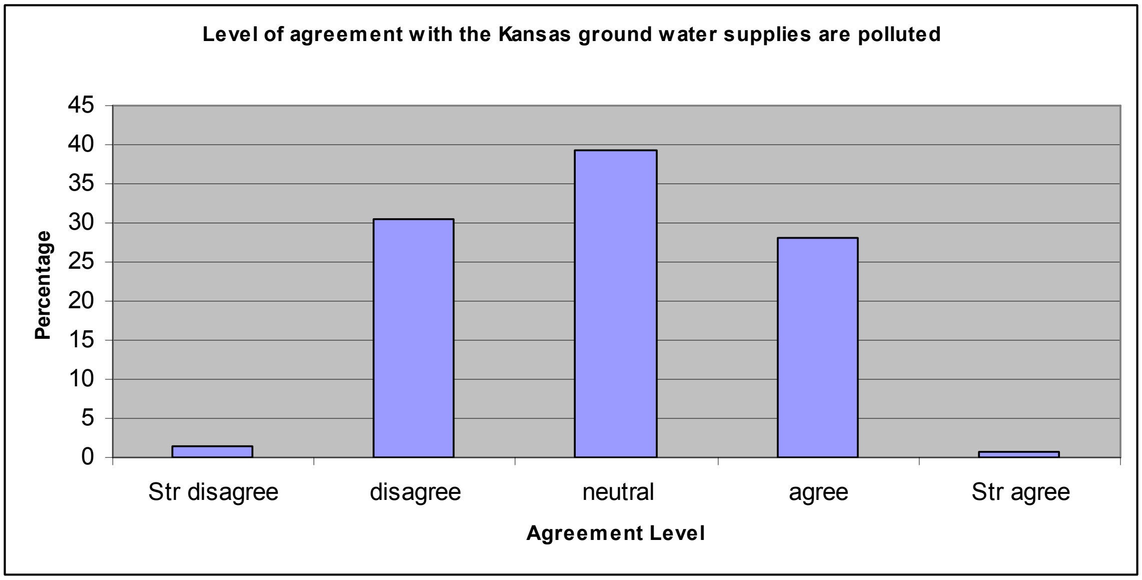
In the survey, respondents were asked to indicated their degree of agreement with statements regarding regulations and the state of water pollution. These responses were subsequently used as measures of farmers' perceptions in the subsequent analysis. Regarding the statement "mandating BMP installation and management is unfair to producers," 3 percent of the respondents strongly disagreed, 18 percent disagreed, 35 percent were neutral, 33 percent agreed, and 11 percent strongly agreed. The responses are illustrated in figure 13.

**Figure 13 – Degree of Agreement to the Statement: Mandating BMP Installation and Management Is Unfair to Producers**



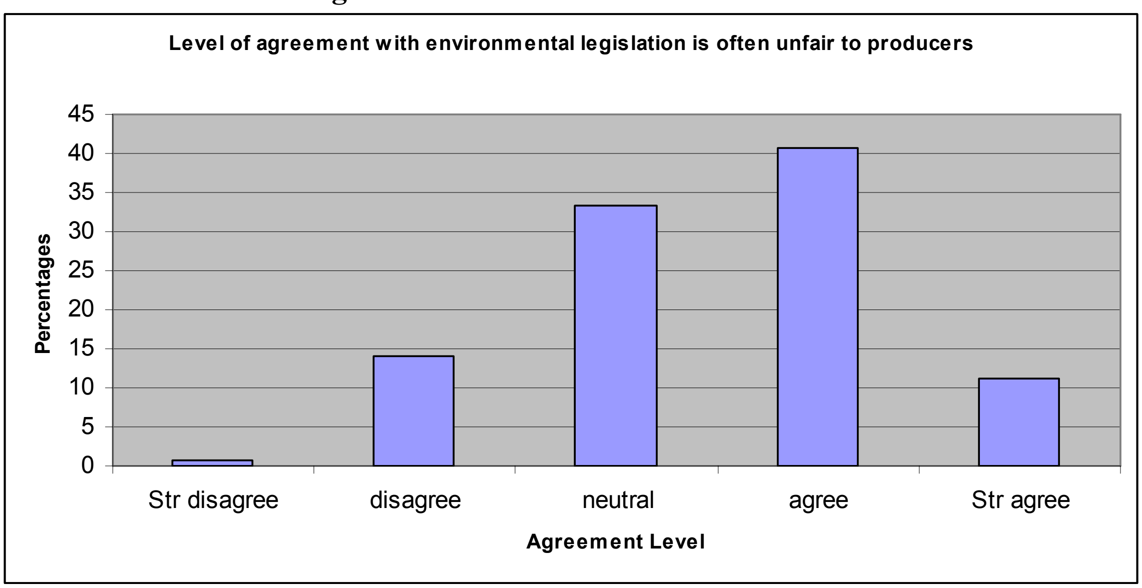

Regarding the statement "Kansas ground water supplies are polluted," 2 percent strongly disagreed, 30 percent disagreed, 39 percent were neutral, 28 percent agreed, and 1 percent strongly agreed. The responses are illustrated in figure 14.

**Figure 14 – Degree of Agreement to the Statement: Kansas Ground Water Supplies Are Polluted**



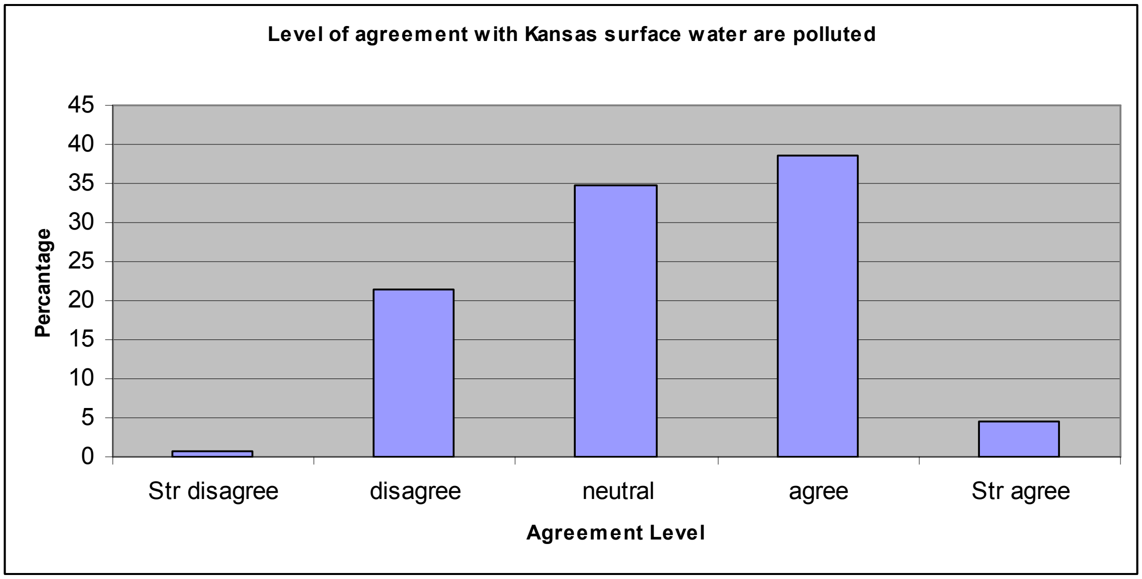

Regarding the statement that environmental legislation is often unfair to producers, 1 percent strongly disagreed, 14 percent agreed, 33 percent were neutral, 41 percent agreed, 11 percent strongly agreed. The responses are illustrated in figure 15.

**Figure 15 – Degree of Agreement to the Statement: Environmental Legislation Is Often Unfair to Producers**



Lastly, regarding the statement that Kansas surface waters are polluted, 1 percent strongly disagreed, 21 percent disagreed, 35 percent were neutral, 38.5 percent agreed, and 4.5 percent strongly agreed. The responses are illustrated in figure 16.

**Figure 16 – Degree of Agreement to the Statement: Kansas Surface Waters Are Polluted**



## Chapter 4: Methods

Farmers can be regarded as going through two stages when making a decision of adopting an environmentally friendly practice the awareness stage and the actual decision stage (Ervin and Ervin, 1982). The first stage is also known as the perception stage, during which the farmers form their understanding regarding the relationship between their farming practices and environmental degradation or their opinions towards environmental regulation. Such farmers' perceptions could vary by demographic factors (for example, age and gender), institutional factors (for example, familiarity and participation with conservation programs such as Conservation Reserve Program (CRP), Environmental Quality Incentive Program (EQIP), Conservation Security Program (CSP), and Kansas Buffer Initiative Program, and membership in Kansas Farm Management Association (KFMA)) and farm characteristics (for example, farm size and presence of bordered water bodies).

Based on the perceptions, the farmers decide whether to adopt the practice that resolves their problem or at least reduces the problem. This is known as adoption stage. At this stage, the decision process is influenced by the perceptions. Other factors that influence the decision process include farmers' attributes, the existing farm programs, and the farm operation attributes.

Thus, the first stage of the analysis deals with the estimation of the perception model. It analyzes the factors that are responsible for the farmers' awareness of the environmental degradation on their farms. The first stage is estimated using ordered logit models. The first stage consisted of four models *y1*, *y2*, *y3* and *y4* respectively. The ordered survey response for these variables were aggregated and scaled from 1 to 3 (1= "strongly disagree" or "disagree", 2 = "neutral" and 3 = "agree" or "strongly agree").

Then, in the adoption stage, the second model uses the predicted values of perception as explanatory variables to explain the dependent variable *y5* (representing the adopted tillage practices in an increasing degree of intensity; 0 = conventional tillage, 1 = minimum tillage, 2 = rotational no-till, and 3 = exclusive no-till). The variable was constructed from the response regarding BMP depicted in figure 2, If the participant carried out more than one best management practice at a time, the value for variable *y5* was assigned as 3 if he followed exclusive no-tillage irrespective of other practices followed. If the participant followed rotational tillage and any other practices but exclusive no-till, then *y5* was assigned as 2. If the participant followed minimum tillage and any other practices but exclusive no-tillage and rotational tillage, then *y5* was assigned as 1. And if the participant followed any other tillage system besides exclusive no-till, rotational no-till, and minimum tillage, then *y5* was assigned 0.

**4.1 The Ordered Logit Model**

Functions where the dependent variable is an ordered response can be estimated using ordered logit models. Aitchison and Silvey (1957) and Cox (1970) discussed how responses can be analyzed using an ordered logit model. They defined the probability that the response of the $i^{th}$ individual $y^*_i$ belonging to the $j^{th}$ category as follows:

$$P\,[\mu_j\text{-}1 < y^*_i < \mu_j] = F\,(\mu_j - x'_i\beta) - F\,(\mu_j\text{-}1 - x'_i\beta),\ i = 1,\ldots J$$

where F( ) is the logistic Cumulative Distributive Function (CDF), $\mu$'s are probability limit parameters with $\mu_0 = -\infty$ and $\mu_j = \infty$, *i* is the respondent, *y* is the indicator variable that denotes the occurrence or nonoccurrence of an event, *j* is the choice of the respondent to the particular question, $x$'s are the explanatory variables and $\beta$'s are the coefficients of the explanatory variables. In this case, $J$ is equal to 3 for models *y1*, *y2*, *y3* and *y4*, and 4 for model *y5*.

In this model the coefficients are not directly related to the marginal effects. In order to compute the marginal effect of discrete variables first the likelihood of farmer's response were calculated and then the marginal effects were computed as follows, using the case for models *y3* and *y5* (Greene, 2003):

$$\partial\, Prob\, [y_i = 1] / \partial x = \{R1 \mid x = 1\} - \{R1 \mid x = 0\}$$

where R1 = $exp\, (\mu_1 - x'\beta) / 1 + exp\, (\mu_1 - x'\beta)$,

$$\partial\, Prob\, [y_i = 2] / \partial x = \{R2 \mid x = 1\} - \{R2 \mid x = 0\}$$

where R2 = $[exp\, (\mu_2 - x'\beta) / 1 + exp\, (\mu_2 - x'\beta)] - R1$,

$$\partial\, Prob\, [y_i = 3] / \partial x = \{R3 \mid x = 1\} - \{R3 \mid x = 0\}$$

where R3 = $[exp\, (\mu_3 - x'\beta) / 1 + exp\, (\mu_3 - x'\beta)] - R2$, and

$$\partial\, Prob\, [y_i = 4] / \partial x = \{R4 \mid x = 1\} - \{R4 \mid x = 0\}$$

where R4 = 1 – (R1 + R2 + R3).

The marginal effects for the continuous variables were computed using the following expression:

$$\partial\, Prob\, [y_i = j] / \partial x = [f\, (\mu_{j-1} - x'_i\beta) - f\, (\mu_j - x'_i\beta)]\, \beta$$

where f( ) is derivative of F( ).

**4.2. Specifications of the Empirical Model**

Several demographic, socioeconomic and farm characteristic variables data from the survey were considered for explaining the perception and adoption stages. The variables used to estimate the logit model were: farm size in acres; the presence of bordered water bodies; profit comparison of no-till practice and other conservation practices; familiarity with and participation in the conservation programs (CRP, EQIP, CSP, and Kansas Buffer Initiative Program); age, gender, primary occupation, and membership in Kansas Farm Management Association. These nine variables were used in all logit regression models, along with regional dummy variables distinguishing the central and eastern regions from the western region of Kansas. See the table 1 for the definition of variables used in the regression models.

**Table 1. Definition of Variables**

| Variables | Definition |
|---|---|
| *y1* | The level of agreement with the "mandating BMP installation and management is unfair to producers " (1 = strongly disagree or disagree; 2 = neutral; and 3 = agree or strongly agree) |
| *y2* | The level of agreement with the "Kansas ground water supplies are polluted" (1 = strongly disagree or disagree; 2 = neutral; and 3 = agree or strongly agree) |
| *y3* | The level of agreement with the "environmental legislation is often unfair to producers" (1 = strongly disagree or disagree; 2 = neutral; and 3 = agree or strongly agree) |
| *y4* | Kansas surface waters are polluted (0 = strongly disagree or disagree; 1 = neutral; and 2 = agree or strongly agree) |
| *y5* | Adopted tillage practice (0 = conventional tillage; 1 = minimum tillage; 2 = rotational no-till; 3 = exclusive no-till) |
| *area1* | Measures Farm size which is scaled by a factor (1,000acres) |
| *bwb* | Farm ground that borders water bodies (include running and dry streams, creeks, rivers, lakes, etc., but not farm ponds) or not (1 = borders; 0 = otherwise) |
| *pfnt* | Profit comparison between no-till and other tillage systems (-3 = Less profitable, by $10/acre or more; -2 = Less profitable, by $5-$10/acre; -1 = Less profitable, by $0-$5/acre; 0 = Equally as profitable; 1 = More profitable, by $0-$5/acre; 2 = More profitable, by $5-$10/acre; and 3 = More profitable, by $10/acre or more) |
| *familiarity* | Familiarity with Conservation Programs ( the number of programs the respondent identified as being familiar, ranging from 0 to 4) |
| *participation* | Participation in Conservation Programs ( the number of programs the respondent indicated as participating, ranging from 0 to 4) |
| *age* | The respondents were asked there actual age in years, but for this particular study the actual ages was converted to categories as summarized in figure 7. |
| *gender* | Gender ( 1 =male; 0 = otherwise) |
| *pocc* | Primary Occupation ( 1 = farming; 0 = otherwise) |
| *mem* | Member of the Kansas Farm Management Association ( 1 = yes; 0 = otherwise) |
| *cent* | Location dummy ( 1 = central region; 0 = otherwise) |
| *east* | Location dummy ( 1 = eastern region; 0 = otherwise) |

There are four perception variables to be analyzed in the first stage: *y1* through *y4*. Variable *y1* measure the extent the farmers perceive whether mandating BMP installation and management is unfair to producers. Variable *y2* is the measure of whether the farmers believe the Kansas ground water supplies are polluted. Variable *y3* measures the farmers' perception of the unfairness of environmental legislation to producers. Lastly, variable *y4* measures the farmers' perception of whether Kansas surface water is polluted. The average response for the variables *y1*, *y2*, *y3*, and *y4* was 2.24, 1.97, 2.37, and 2.21 based on a scale of 1 to 3, 1 being disagree or strongly disagree and 3 being agree or strongly agree. Model $y_k$, $k$ = 1 through 4, aim at examining the factors that contribute to bring the farmers awareness of environmental degradation on their farms, and is defined as:

$$yk = \beta_0 + \beta_1 area + \beta_2 bwb + \beta_3 pfnt + \beta_4 familiarity + \beta_5 participation + \beta_6 age + \beta_7 gender + \beta_8 pocc + \beta_9 mem + \beta_{10} cent + \beta_{11} east + \varepsilon_k$$

In the second stage, variable *y5* represents the adoption of various tillage practices in an increasing degree of intensity. The variable was regressed on the same explanatory variables as the first stage models, and in addition, the four perception variables *y1*, *y2*, *y3*, and *y4* were also included in the regression.

SAS statistical software was used to obtain maximum-likelihood estimation of the ordered logit models. A likelihood ratio test was conducted for the adoption model to test if the perception variables were exogenous or endogenous in the adoption equation (i.e., determined simultaneously with the adoption decision). The models were regressed with actual and predicted values and tested for the joint significance of the predicted perception variables. The null hypothesis for the exogeneity test is that the coefficients on the predicted values of the perception variables are jointly equal to zero. The likelihood ratio test was conducted using the formula (Maddala, 1983):

2[LL of restricted model – LL of unrestricted model]

where LL stands for the log likelihood value. The resulting value was compared to critical values of a chi-square distribution with *r* degrees of freedom, where *r* is the number of restrictions. An alpha level of 0.05 was used for all of the likelihood ratio tests.

## Chapter 5: Results

### 5.1 Exogeneity Results

The results of the likelihood ratio tests are summarized in Table 2

**Table 2. Exogeneity Results**

| | Model y5 |
|---|---|
| Test Statistics | 1.399 |
| r | 4 |
| Critical Value | 9.488 |
| Conclusion | Cannot Reject $H_0$ |

Exogeneity results conclude that the null hypothesis of exogeneity cannot be rejected and therefore we use the observed values of the perception variables in the equation. That is, the *y5* equation was estimated as follows:

$$y5 = \beta_0 + \beta_1 y1 + \beta_2 y2 + \beta_3 y3 + \beta_4 y4 + \beta_5 area + \beta_6 bwb + \beta_7 pfnt + \beta_8 familairity + \beta_9 participation + \beta_{10} age + \beta_{11} gender + \beta_{12} pocc + \beta_{13} mem + \beta_{14} cent + \beta_{15} east + \varepsilon_5$$

### 5.2 Perception Models

The results of the perception models from *y1* through *y4* are summarized in tables 3, 5, 7, and 9 respectively and the marginal effects are summarized in tables 4, 6, 8, and 10, respectively.

**Table 3. Ordered Logit Model Estimation Results for Model y1**

| Parameter | Estimate | Standard Error | t-value | Pr > \|t\| |
|---|---|---|---|---|
| *area1* | -0.069 | 0.083 | -0.83 | 0.406 |
| *bwb* | 0.710 | 0.457 | 1.56 | 0.120 |
| *pfnt* | -0.096 | 0.105 | -0.91 | 0.361 |
| *familiarity* | -0.045 | 0.190 | -0.23 | 0.815 |
| *participation* | -0.030 | 0.234 | -0.13 | 0.900 |
| *age* | -0.004 | 0.013 | -0.30 | 0.768 |
| *gender* | 0.039 | 0.517 | 0.07 | 0.940 |
| *pocc* | 0.161 | 0.422 | 0.38 | 0.702 |
| *mem* | -0.019 | 0.496 | -0.04 | 0.970 |
| *cent* | 0.072 | 0.460 | 0.16 | 0.876 |
| *east* | 0.394 | 0.548 | 0.72 | 0.472 |
| *Limit1* | -1.082 | 0.831 | -1.30 | 0.193 |
| *Limit2* | 0.580 | 0.826 | 0.70 | 0.483 |

**Table 4. Marginal Effects of the Variables in Model y1**

| Parameter | Marginal effect on the probability of y1 = 1 | Marginal effect on the probability of y1 = 2 | Marginal effect on the probability of y1 = 3 |
|---|---|---|---|
| *area1* | 0.010 | 0.005 | -0.015 |
| *bwb* | -0.145 | 0.097 | 0.048 |
| *pfnt* | 0.014 | 0.007 | -0.020 |
| *familiarity* | 0.109 | -0.136 | 0.027 |
| *participation* | 0.007 | -0.004 | -0.002 |
| *age* | 0.001 | 0.000 | -0.000 |
| *gender* | -0.009 | 0.010 | -0.001 |
| *pocc* | -0.036 | 0.023 | 0.012 |
| *mem* | 0.004 | -0.003 | -0.001 |
| *cent* | -0.015 | 0.010 | 0.005 |
| *east* | -0.089 | 0.056 | 0.033 |

As per table 3, there were no variables that were statistically significant at the 5 percent and 10 percent levels, suggesting that the farm operators' perception regarding whether BMP installation and management is unfair to producers or not do not vary systematically across farm size, producers' familiarity or participation in conservation programs, or other demographics.

**Table 5. Ordered Logit Model Estimation Results for Model y2**

| Parameter | Estimation | Standard Error | t-value | Pr > \|t\| |
|---|---|---|---|---|
| *area1* | 0.018 | 0.086 | 0.21 | 0.836 |
| *bwb* | 0.072 | 0.436 | 0.16 | 0.869 |
| *pfnt* | -0.205 | 0.110 | -1.87 | 0.062 |
| *familiarity* | 0.064 | 0.194 | 0.33 | 0.742 |
| *participation* | 0.076 | 0.229 | 0.33 | 0.741 |
| *age* | -0.004 | 0.013 | -0.34 | 0.735 |
| *gender* | 0.529 | 0.533 | 0.99 | 0.321 |
| *pocc* | -0.891 | 0.444 | -2.01 | 0.045 |
| *mem* | 0.146 | 0.478 | 0.31 | 0.759 |
| *cent* | 0.179 | 0.487 | 0.37 | 0.713 |
| *east* | -0.308 | 0.539 | -0.57 | 0.567 |
| *Limit1* | -0.956 | 0.844 | -1.13 | 0.257 |
| *Limit2* | 0.914 | 0.844 | 1.08 | 0.279 |

**Table 6. Marginal Effects of the Variables in Model y2**

| Parameter | Marginal effect on the probability of y2 = 1 | Marginal effect on the probability of y2 = 2 | Marginal effect on the probability of y2 = 3 |
|---|---|---|---|
| *area1* | -0.003 | 0.000 | 0.003 |
| *bwb* | -0.013 | -0.002 | 0.016 |
| *pfnt* | 0.037 | -0.001 | -0.035 |
| *familiarity* | -0.013 | 0.000 | 0.013 |
| *participation* | -0.014 | -0.002 | 0.016 |
| *age* | 0.000 | 0.000 | 0.000 |
| *gender* | -0.105 | -0.004 | 0.109 |
| *pocc* | 0.155 | 0.044 | -0.199 |
| *mem* | -0.026 | -0.006 | 0.033 |
| *cent* | -0.032 | -0.009 | 0.040 |
| *east* | 0.061 | 0.002 | -0.063 |

Table 5 shows the variables statistically significant at 10 percent and 5 percent levels were *pfnt* and *pocc*, respectively, and their marginal effects can be interpreted as follows from table 6.

If the respondents believed that no-till is equally or more profitable than other tillage systems, then the likelihood of the farmer agreeing that the Kansas ground water supplies are polluted decreased by 0.035, decreased the probability of the farmer remaining neutral to the statement by 0.001, and increased the probability of the farmer disagreeing to the statement by 0.037. If the respondent's primary occupation was farming/ranching, then the likelihood of the farmer agreeing that the Kansas ground water supplies are polluted decreased by 0.199, increased the probability of the farmer remaining neutral to the statement by 0.044, and increased the probability of the farmer disagreeing to the statement by 0.155.

**Table 7. Ordered Logit Model Estimation Results for Model y3**

| Parameter | Estimate | Standard Error | t-value | Pr > \|t\| |
|---|---|---|---|---|
| *area1* | 0.064 | 0.094 | 0.68 | 0.499 |
| *bwb* | 0.251 | 0.467 | 0.54 | 0.591 |
| *pfnt* | 0.083 | 0.118 | 0.71 | 0.481 |
| *familiarity* | -0.133 | 0.202 | -0.66 | 0.511 |
| *participation* | -0.389 | 0.237 | -1.64 | 0.101 |
| *age* | 0.008 | 0.014 | 0.61 | 0.544 |
| *gender* | 0.432 | 0.514 | 0.84 | 0.400 |
| *pocc* | 0.436 | 0.435 | 1.00 | 0.316 |
| *mem* | 0.525 | 0.555 | 0.95 | 0.344 |
| *cent* | -0.400 | 0.474 | -0.84 | 0.398 |
| *east* | 0.222 | 0.571 | 0.39 | 0.697 |
| *Limit1* | -1.247 | 0.887 | -1.41 | 0.160 |
| *Limit2* | 0.468 | 0.879 | 0.53 | 0.594 |

**Table 8. Marginal Effects of the Variables in Model y3**

| Parameter | Marginal effect on the probability of y3 = 1 | Marginal effect on the probability of y3 = 2 | Marginal effect on the probability of y3 = 3 |
|---|---|---|---|
| *area1* | -0.007 | -0.005 | 0.013 |
| *bwb* | -0.015 | -0.035 | 0.050 |
| *pfnt* | -0.007 | -0.007 | 0.016 |
| *familiarity* | 0.006 | 0.016 | -0.022 |
| *participation* | 0.019 | 0.051 | -0.070 |
| *age* | -0.001 | -0.001 | 0.002 |
| *gender* | -0.028 | -0.061 | 0.089 |
| *pocc* | -0.026 | -0.060 | 0.086 |
| *mem* | -0.026 | -0.067 | 0.093 |
| *cent* | 0.024 | 0.055 | -0.079 |
| *east* | 0.010 | -0.028 | 0.037 |

Table 7 shows that no variables were statistical significance at 5 percent and 10 percent level. Similar to the farm operators' perception of fairness regarding BMP installation and management, the results suggest that their perception of fairness regarding environmental regulation do not vary systematically across farm size, producers' familiarity or participation in conservation programs, or other demographics.

**Table 9. Ordered Logit Model Estimation Results for Model y4**

| Parameter | Estimate | Standard Error | t-value | Pr > \|t\| |
|---|---|---|---|---|
| *area1* | 0.014 | 0.090 | 0.15 | 0.880 |
| *bwb* | 0.019 | 0.470 | 0.04 | 0.967 |
| *pfnt* | -0.042 | 0.105 | -0.40 | 0.690 |
| *familiarity* | 0.345 | 0.197 | 1.75 | 0.079 |
| *participation* | -0.228 | 0.229 | -1.00 | 0.319 |
| *age* | 0.021 | 0.013 | 1.62 | 0.104 |
| *gender* | -0.036 | 0.515 | -0.07 | 0.945 |
| *pocc* | -0.544 | 0.434 | -1.25 | 0.210 |
| *mem* | -0.210 | 0.501 | -0.42 | 0.675 |
| *cent* | 0.050 | 0.478 | 0.10 | 0.917 |
| *east* | -0.199 | 0.543 | -0.37 | 0.714 |
| *Limit1* | -0.199 | 0.875 | -0.23 | 0.820 |
| *Limit2* | 1.517 | 0.883 | 1.72 | 0.086 |

**Table 10. Marginal Effects of the Variables in Model y4**

| Parameter | Marginal effect on the probability of y4 = 1 | Marginal effect on the probability of y4 = 2 | Marginal effect on the probability of y4 = 3 |
|---|---|---|---|
| *area1* | -0.002 | -0.011 | 0.031 |
| *bwb* | -0.003 | -0.002 | 0.005 |
| *pfnt* | 0.006 | 0.003 | 0.009 |
| *familiarity* | -0.072 | 0.000 | 0.072 |
| *participation* | 0.030 | 0.027 | -0.057 |
| *age* | -0.003 | -0.001 | 0.004 |
| *gender* | 0.005 | 0.004 | -0.009 |
| *pocc* | 0.072 | 0.063 | -0.135 |
| *mem* | 0.030 | 0.022 | -0.052 |
| *cent* | -0.006 | -0.006 | 0.012 |
| *east* | 0.029 | 0.020 | -0.049 |

Table 9 shows that *familiarity* is statistical significant at the 10 percent level and its marginal effects can be interpreted as follows from table 10. If the respondents were familiar with more conservation programs, then the likelihood of the respondent agreeing that the Kansas surface water are polluted increased by 0.072, and decreased the probability of the respondent disagreeing to the statement by 0.072, all else equal.

### 5.3 Adoption Model

The adoption model was estimated using SAS and the marginal effect of the respective independent variables over the dependent variable was calculated. The marginal effect of the binary independent variables and the regional dummy variables were calculated using Excel and the marginal effect for the continuous variables and perception variables were computed using SAS as averages of the marginal effects for all respondents. Model *y5* was designed to determine the factors affecting the adoption of no-tillage systems against the other tillage systems. Estimated coefficients for model *y5* are summarized in table 11, and the marginal effects of the variables are summarized in table 12.

**Table 11. Ordered Logit Model Estimation Results for Model y5**

| Parameter | Estimate | Standard Error | t-value | Pr > \|t\| |
|---|---|---|---|---|
| *y1* | -0.343 | 0.247 | -1.39 | 0.165 |
| *y2* | 0.087 | 0.285 | 0.31 | 0.760 |
| *y3* | 0.440 | 0.272 | 1.62 | 0.106 |
| *y4* | -0.300 | 0.301 | -1.00 | 0.320 |
| *area1* | 0.186 | 0.103 | -1.80 | 0.071 |
| *bwb* | -0.685 | 0.495 | -1.38 | 0.167 |
| *pfnt* | 0.632 | 0.127 | 4.98 | <.0001 |
| *familiarity* | 0.425 | 0.208 | 2.04 | 0.041 |
| *participation* | 0.655 | 0.254 | 2.58 | 0.010 |
| *age* | 0.015 | 0.013 | 1.11 | 0.266 |
| *gender* | 0.432 | 0.520 | 0.83 | 0.406 |
| *pocc* | -0.150 | 0.438 | -0.34 | 0.731 |
| *mem* | 0.765 | 0.531 | 1.44 | 0.150 |
| *cent* | 0.308 | 0.489 | 0.63 | 0.529 |
| *east* | 0.606 | 0.559 | 1.08 | 0.279 |
| *Limit1* | 0.298 | 1.270 | 0.23 | 0.815 |
| *Limit2* | 2.049 | 1.274 | 1.61 | 0.108 |
| *Limit3* | 4.332 | 1.323 | 3.27 | 0.001 |

**Table 12. Marginal Effects of the Variables in Model y5**

| Parameter | Marginal Effect on the probability of y5 = 0 | Marginal Effect on the probability of y5 = 1 | Marginal Effect on the probability of y5 = 2 | Marginal Effect on the probability of y5 = 3 |
|---|---|---|---|---|
| *y1* | 0.025 | 0.023 | -0.005 | -0.043 |
| *y2* | -0.006 | -0.006 | 0.001 | 0.011 |
| *y3* | -0.033 | -0.029 | 0.007 | 0.055 |
| *y4* | 0.022 | 0.020 | -0.004 | -0.037 |
| *area1* | -0.014 | -0.012 | 0.003 | 0.023 |
| *bwb* | 0.004 | 0.016 | 0.105 | -0.125 |
| *pfnt* | -0.047 | -0.042 | 0.009 | 0.079 |
| *familiarity* | -0.007 | -0.027 | -0.079 | 0.113 |
| *participation* | -0.005 | -0.023 | -0.118 | 0.146 |
| *age* | -0.001 | -0.001 | 0.000 | 0.002 |
| *gender* | -0.003 | -0.014 | -0.076 | 0.093 |
| *pocc* | 0.000 | 0.004 | 0.025 | -0.030 |
| *mem* | -0.004 | -0.017 | -0.114 | 0.135 |
| *cent* | -0.002 | -0.010 | -0.054 | 0.066 |
| *east* | -0.004 | -0.017 | -0.101 | 0.122 |

Table 11 shows the variables that were statistically significant at the 5 percent and 10 percent levels are *area1*, *pfnt*, *familiarity*, and *participation*. None of the perception variables were statistically significant at the 10 percent level. The marginal effects of these variables can be interpreted as follows from the table 12.

If the operated acreage of the respondents increased by 1,000 acres, then the likelihood of the respondent adopting exclusive no-till increased by 0.023, increased the probability of the respondent considering to adopt rotational no-till by 0.003, decreased the probability of the respondent considering to adopt minimum tillage by 0.012, and decreased the probability of the respondent considering to adopt more conventional systems by 0.014, holding everything else equal.

If the respondents agree that the profits from no-till are equal to or more than other systems, then the likelihood of the respondent considering to adopt exclusive no-till increased by 0.079, increased the probability of the respondent considering to adopt rotational no-till by 0.009, decreased the probability of the respondent considering to adopt minimum tillage by 0.042, and decreased the probability of the respondent considering to adopt other systems by 0.047, holding everything else equal.

If the respondent was familiar with more conservation programs, then the likelihood of the respondent considering to adopt exclusive no-till increased by 0.113, decreased the probability of the respondent considering to adopt rotational no-till by 0.079, decreased the probability of the respondent considering to adopt minimum tillage by 0.027, and decreased the probability of the respondent considering to adopt other systems by 0.007, holding everything else equal.

If the respondent participated in more conservation programs, then the likelihood of the respondent adopting exclusive no-till increased by 0.146, decreased the probability of the respondent considering to adopt rotational no-till by 0.118, decreased the probability of the respondent considering to adopt minimum tillage by 0.023, and decreased the probability of the respondent considering to adopt other systems by 0.005, holding everything else equal.

The marginal effects for *area1* suggest that larger farmers are more likely to adopt more modern (progressive) technologies than smaller farmers. The literature suggests that this can be explained by larger farmers facing lower credit constraint and their scale of operation allowing them to spread the fixed cost of technology adoption. Also, the marginal effects for *pfnt* suggest that the technology is more likely to be adopted if it is perceived to be more profitable.

The marginal effect for participation in conservation programs is larger than those for other factors, which can be explained by the fact that no-tillage is one of the requirements to receive CSP payments.

**5.4. Discussion**

In model *y2* the *pfnt* and *pocc* variables were statistically significant, and their marginal effects seemed to suggest that the respondent perceived that no-till was more profitable than other tillage practices, or if the respondent's primary occupation was farming or ranching then it decreased the probability of the respondents to agree that the Kansas ground water supplies are polluted. The possibly contradictory results may be reflecting that reasons why respondents may adopt no-till or other conservation tillage systems are not related to their perceived contribution to the level of pollution of water supply, but rather related to the perceived profitability of the conservation tillage systems, which is what the adoption model results suggest. This association is likely stronger for those who are primarily involved in farming or ranching. If so, this would be in contrast to some findings that farmers are reluctant to adopt eco-friendly process for monetary payments (e.g., Cooper and Keim, 1996).

In model *y4 familiarity* was the only statistically significant variable and its marginal effect seemed to suggest that the familiarity with the conservation programs increased the probability of the respondent to agree that Kansas surface water are polluted. This is because conservation programs give a better understanding of the water quality and this knowledge will help the farmers to assess whether or not Kansas surface water are polluted.

In model y5 the *area1*, *pfnt*, *familiarity*, and *participation* variables were statistically significant, and their marginal effects seemed to suggest that increase in operating acreage, if profits are equal to or more than other tillage systems, familiarity with and participation in conservation programs increased the probability of the respondents to adopt no-tillage system. This may be due to various reasons such as reduced production cost, increased yields and profits, knowledge gained from various conservation programs, understanding the importance of adoption of BMPs, and understanding the impact of environmental degradation and thus trying to maintain the ecological balance.

The results of the adoption model may contribute to the interest of the USDA of speeding up the adoption of conservation tillage practices such as no-till. From table 12 *pfnt* variable being statistically significant and the perception variables being not statistically significant suggest that the adoption is motivated by farmer's perception that the technology is profitable and not by their perceptions of environmental policies. Similarly, *familiarity* and *participation* being statistically significant indicated that awareness and knowledge of the technologies through familiarity with and participation in conservation programs motivates the farmer's to adopt modern (innovative) technologies.

## Chapter 6: Conclusion

Adequate knowledge about the damages caused to the environment due to agriculture has brought awareness among the farmers and has led to a general consensus that farmers should be induced to adopt more environmental friendly practices. The main objective of this study was to identify the impacts of the various factors affecting the adoption of conservation practices in Kansas agriculture. The farmers' decisions were modeled as a two-stage process, consisting of the formation of perception towards environment related practices and programs and the actual adoption of various conservation tillage practices. Models were built using ordered logit regressions to estimate how much the independent variables affected the farmer's perception regarding best management practices, surface water quality and the environmental legislation, and then to estimate how such perceptions along with other factors affected the actual adoption decisions.

The study was concerned with farmer's perception for four issues: whether mandating BMP installation and management is unfair to producers, whether or not environmental legislation was often unfair to the producers, whether or not Kansas ground water supplies are polluted, and whether or not Kansas surface waters were polluted. The factors considered in this study included farm characteristics, farmer characteristics, institutional factors, and demographic variables: farm size, presence of bordered water bodies, profit comparison of no-till system with other tillage systems, familiarity and participation in Conservation Reserve Program, Environmental Quality Incentive Program, Conservation Security Program, and Kansas Buffer Initiative

Program, age, gender, primary occupation, membership in Kansas Farm Management Association, and location dummies.

The results for the perception models showed that the farm operators' perceptions regarding whether BPM installation and management is unfair to producers or not and whether environmental legislation is often unfair to producers do not vary systematically across farm size, producers' familiarity and participation in conservation programs, or other demographics considered in the study. On the other hand, their perceptions regarding how polluted their water supplies varied by their thoughts on relative profitability across various tillage practices, their primary occupation, and their familiarity with conservation programs. Specifically, the results suggested that those who regarded no-till practices to be more profitable than other tillage practices or whose primary occupation was farming-related tended to believe that ground water was not polluted, and those who were less familiar with available conservation programs tended to believe that surface water s were not polluted.

Later the study was concerned about the factors influencing the adoption of conservation practices. Similarly, logit regression model was used to determine factors influencing the adoption of conservation practices. As expected the adoption model *y5* did capture some statistically significant factors. Specifically, the results suggested that farmers with greater operating acreage, those who perceived that no-till was more profitable than other tillage systems, and those with greater familiarity with and participation in existing conservation programs were more likely to adopt more conservation tillage systems, all else equal. Further, perceptions of fairness of environmental regulations or the level of pollution did not impact the tillage choices.

The findings are subject to methodological limitations. For example, the models might not have accounted for all relevant factors or the variables might not have captured the actual intendedconcepts. Perhaps because of the heterogeneity in the people's decision, these models might have failed to capture the overall tendency, or the data set was likely too small to capture the variability of variables among the farming population. Further studies with larger sample size and different models can be conducted in this area in order to check the factors influencing the farmer's perception, adoption of conservation practices, and the participation in various institutional programs. At the same time, this study stresses the importance of promoting an understanding of relative profitability of conservation tillage practices, since the adoption of no-till among the Kansas farmers in this study were clearly motivated by perceived profitability.

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## Appendix: The Survey

# Water Quality Trading Questionnaire

### Section 1: Your Cropland

1. *How many cropland acres do you farm/manage? (Include land in fallow, but do not include pasture/range land or land rented out.)*

   a. *Owned cropland* ____________ *acres*

   b. *Rented cropland* ____________ *acres*

2. *Do you have farm ground that borders water bodies (Include running and dry streams, creeks, rivers, lakes, etc., but do not include farm ponds)?*
   ❐ *Yes* ❐ *No*

3. *Which Best Management Practices do you currently use in your farming operation? (Check all that apply.)*
   ❐ *Filter strip*
   ❐ *Rotational No-till*
   ❐ *Terraces*
   ❐ *Contour farming*
   ❐ *Minimum tillage*
   ❐ *Exclusive (100%) No-till*
   ❐ *Sub-surface application of fertilizer*
   ❐ *Other:* __________________

4. *K-State research suggests that no-till generates about the same profit per acre as other tillage systems for an* ***average*** *Kansas farm. On* ***your farm****, is no-till more or less profitable than other tillage systems? (Check only one.)*

   ❐ *More profitable, by $10/acre or more*
   ❐ *More profitable, by $0 - $5/acre*
   ❐ *Less profitable, by $0 - $5/acre*
   ❐ *Less profitable, by $10/acre or more*
   ❐ *More profitable, by $5 - $10/acre*
   ❐ *Equally as profitable*
   ❐ *Less profitable, by $5 - $10/acre*

5. *Are you familiar with the following conservation programs? Have you ever participated in them?*

| *Program* | *Familiar with?* | *Participated in?* |
|---|---|---|
| *Conservation Reserve Program (CRP)* | ❐ *Yes* ❐ *No* | ❐ *Yes* ❐ *No* |
| *Environmental Quality Incentives Program (EQIP)* | ❐ *Yes* ❐ *No* | ❐ *Yes* ❐ *No* |
| *Conservation Security Program (CSP)* | ❐ *Yes* ❐ *No* | ❐ *Yes* ❐ *No* |
| *Kansas Buffer Initiative* | ❐ *Yes* ❐ *No* | ❐ *Yes* ❐ *No* |

### Section 2: Perceptions

*Indicate your level of agreement or disagreement with each of the following statements. There are no right or wrong responses.*

6. *Best management practices (BMPs) reduce nutrient and sediment runoff.*
   ❐ *Strongly disagree* ❐ *Disagree* ❐ *Neutral* ❐ *Agree* ❐ *Strongly agree*

7. *Kansas surface water quality needs to be protected.*
   ❐ *Strongly disagree* ❐ *Disagree* ❐ *Neutral* ❐ *Agree* ❐ *Strongly agree*

8. *Kansas ground water quality needs to be protected.*
❒ Strongly disagree ❒ Disagree ❒ Neutral ❒ Agree ❒ Strongly agree

9. *Mandating BMP installation and management is unfair to producers.*
❒ Strongly disagree ❒ Disagree ❒ Neutral ❒ Agree ❒ Strongly agree

10. *Environmental legislation is often unfair to producers.*
❒ Strongly disagree ❒ Disagree ❒ Neutral ❒ Agree ❒ Strongly agree

11. *Kansas surface waters are polluted.*
❒ Strongly disagree ❒ Disagree ❒ Neutral ❒ Agree ❒ Strongly agree

12. *Kansas groundwater supplies are polluted.*
❒ Strongly disagree ❒ Disagree ❒ Neutral ❒ Agree ❒ Strongly agree

13. *A farmer who participates in a water quality trading market is more likely to be regulated in the future, compared to nonparticipants.*
❒ Strongly disagree ❒ Disagree ❒ Neutral ❒ Agree ❒ Strongly agree

14. *If water quality trading markets emerge and are successful, future government regulations on agriculture will be more stringent than otherwise.*
❒ Strongly disagree ❒ Disagree ❒ Neutral ❒ Agree ❒ Strongly agree

15. *How would you rate your knowledge of Water Quality Trading before you attended this conference?*
❒ Very Low ❒ Low ❒ Medium ❒ High ❒ Very High

16. *How would you rate your knowledge of Water Quality Trading now?*
❒ Very Low ❒ Low ❒ Medium ❒ High ❒ Very High

### *Section 3: About You*

*The following questions will help us learn more about crop producers in the Great Plains.* ***We would like to remind you that your responses are strictly confidential and anonymous - they cannot be associated with you personally.***

17. *Are you...❒ Male ❒Female*

18. *What is your age? _____ Years*

19. *Years of formal education? _____ (12=high school graduate, 16=college graduate, etc.)*

20. *Which of the following best describes your occupation?*
❒ Farmer/Rancher ❒ Landowner not actively farming ❒ Land manager
❒ Lender/farm advisosr/educator ❒ Other

21. *Is farming/ranching your primary occupation? ❒Yes ❒No*

22. *In which county (or counties) do you actively farm? ____________________*
*State if not from Kansas ______________________*

23. *If you farm in more than one county, which do you consider the primary county for your farming operation?* ________________________

24. *Are you a member of the Kansas Farm Management Association?* ❒ Yes ❒ No

**Section 4: Follow Up**

25. *In your opinion, what features should be included in a Water Quality Trading market to encourage the largest number of producers to participate?*

______________________________________________

______________________________________________

______________________________________________

______________________________________________

26. *There are many conservation programs currently in place that offer financial incentives. In your opinion, why do some producers choose not to participate in these programs?*

______________________________________________

______________________________________________

______________________________________________

______________________________________________

27. *In your opinion, why might agricultural producers choose **not** to participate in a Water Quality Trading market?*

______________________________________________

______________________________________________

______________________________________________

______________________________________________

***Thank You For Your Time***

## Water Quality Trading Questionnaire

Kansas State University
Department of Agricultural Economics
Participant # ________

# Water Quality Trading Questionnaire

*This questionnaire asks you about the characteristics of your farm, your perceptions about water quality issues, and some demographic information about you.*
*We can assure you that all of the information you provide will be treated as strictly confidential and that your responses can never be associated with you personally. Your participation is voluntary and can be terminated at any time. Questions or concerns about this questionnaire can be directed to any of the contact persons below.*

***Many thanks for your assistance in this research.***

### Instructions

- *Please answer **all** of the questions below as accurately as you can.*
- *Please write **legibly**.*
- *If you wish to comment on any questions or qualify your answers, please feel free to use the space in the margins. Your comments will be read and taken into account.*
- *Return this questionnaire and the Water Quality Trading Experiment booklet to the presenter in your session.*

### Contact Persons

*For questions or concerns about this research, please contact any of these individuals:*

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