THESIS

FACTORS INFLUENCING THE ADOPTION OF BEST MANAGEMENT PRACTICES FOR FEEDLOT AMMONIA EMISSIONS

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY CAROLYN DAVIDSON ENTITLED FACTORS INFLUENCING THE ADOPTION OF BEST MANAGEMENT PRACTICES FOR FEEDLOT AMMONIA EMISSIONS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

FACTORS INFLUENCING THE ADOPTION OF BEST MANAGEMENT PRACTICES FOR FEEDLOT AMMONIA EMISSIONS

Gaseous ammonia emissions from feedlot operations pose serious risks to human and ecosystem health. In particular, nitrogen deposition in Colorado's Rocky Mountain National Park may be associated with livestock feeding in the western Corn Belt and Colorado. Feedlot operators can implement a variety of Best Management Practices (BMPs) to reduce ammonia emissions. These BMPs vary in effectiveness, simplicity, managerial time, effort and financial capital. Although the ammonia-mitigating potential of various BMPs is well-researched, little research examines the barriers that prevent feedlot operations from adopting these BMPs. This research uses discrete choice modeling to evaluate factors influencing adoption for the average producer as well as subsets of producers. Explanatory variables include farm characteristics as well as operator perceptions of cost, profitability, ease of adoption, and environmental impact. Size of operation and perception of profitability of a given BMP most impact probability of adoption, indicating that cost-sharing programs may assist adoption.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

U.S. livestock operations have undergone a drastic transformation in the past few decades, becoming, on average, larger and more geographically concentrated. With this growth has come an increased concentration of air and water pollutants. Confined animal feeding operations of a certain size became regulated under the Clean Water Act, but air pollutants have avoided similar regulation. As of late, ammonia emissions, previously considered primarily a nuisance odor, have come to the center of the regulatory stage.

Feedlot operations produce ammonia as an externality, a negative cost to society that is not internalized in operating costs. In such cases, government intervention is one policy option to lead operators to internalize these social costs. However, non-point source regulation can be extremely costly, both in terms of collecting information on emissions as well as enforcing regulations. Requiring operations to implement specific ammonia-reducing practices could lead to higher costs compared to the benefits of regulation. Furthermore, many feedlot operations already use ammonia-reducing best management practices (BMPs) suited to their operation. This study is part of a larger effort by the National Resource Conservation Service to determine the most effective ammonia BMPs as well as methods to encourage voluntary adoption by feedlot operators. This decision is ultimately economic in nature, since adopting may require the operator to divert time and money from other allocations within the operation. A better understanding of producer incentives and disincentives to adopting BMPs will allow outreach personnel to target specific barriers to adoption, as well as adapt their strategy to the attributes of a given operation.

In order to gather data on this decision, a survey was sent out to feedlot operations in four states in order to assess the current adoption rates of thirteen BMPs that were selected as having a high potential to reduce ammonia emissions. In addition to BMP adoption information, the survey collected information on the operation size, operating revenue, age of operator and investment capabilities. Similar studies found that a combination of farm and operator characteristics, as well as perceptions pertaining to the particular BMP can influence adoption (Rahelizatovo, 2002). This study used univariate and multivariate discrete choice analysis to determine whether hypothesized variables influenced adoption in this sample, and furthermore, whether these conclusions can be applied to the greater population of feedlot operations. Finally, these results aimed to motivate policy recommendations that are better tailored to individual operations by identifying adoption constraints specific to BMPs, particularly, cost and technology constraints.

1.2 Problem Statement

Gaseous ammonia emissions from feedlot operations pose serious risks to human and ecosystem health. Exposure to even low levels of ammonia can irritate the lungs and eyes, and, when in fine particulate matter form, can cause a variety of respiratory ailments. A 2003 study by the National Research Council identified ammonia emissions as a major air quality concern at regional, national, and global levels (NRC, 2003). The U.S. Environmental Protection Agency (EPA) estimated that animal agriculture accounts for 50 percent to 85 percent of total man-made ammonia volatilization in the United States, nearly half of which is estimated to come from cattle (Battye et al., 1994). On a regional level, nitrogen deposition in Colorado's Rocky Mountain National Park has been associated with livestock feeding in the western Corn Belt and Colorado. Half of the 14 million fed cattle in the nation are found in Nebraska, Kansas, Colorado and Iowa. In fact, these four states are ranked 2nd, 3rd, 4th and 5th, respectively, in terms of number of feed cattle (NASS, 2008).

A variety of BMPs can minimize ammonia emissions in the production facility and where it is stored, processed and applied to the land. Some of the practices, such as reducing the level of crude protein in an animal's diet, are simple and cost effective, while others require technical assistance and financial resources. Indeed, the effectiveness of various BMPs in reducing emissions is well-researched (see Marcillac *et al.*, 2007 for a comprehensive literature review). However, little research exists on whether producers adopt these practices or the motivation behind the adoption decision. Specifically, no research has explored specific barriers that feedlot operators face when deciding whether to adopt.

Constraints to adoption may take a variety of forms. Constraints could be of a physical nature; producers could be limited by lump sum cash, cash flows, or labor. Alternatively, bounded rationality may constrain a producer- access to information on the available BMPs is simply infeasible. Extension and outreach personnel are one means for creating access, so information on producer adoption and constraints will inform their outreach strategy. Developing an understanding of adoption levels would allow them to promote more commonly adopted BMPs, or, alternatively, promoting an overlooked BMP. Better understanding specific motivations to adopt could help direct policies or educational tools that would reduce operator barriers. Developing this information, which outreach professionals can combine with their knowledge on the ammonia reduction potential of each BMP, is an important step towards efficiently reducing net ammonia emissions.

1.3 Objectives of the Study

This study surveyed feedlot producers in Colorado, Iowa, Nebraska and Kansas regarding their use of ammonia BMPs to determine the role of socioeconomic characteristics, feedlot operation characteristics and operator perceptions on the adoption of selected BMPs for ammonia emissions. Meeting this objective would improve the effectiveness of outreach efforts by enabling outreach professionals to more appropriately match outreach strategy with operator needs. Furthermore, this information may allow regulatory and technical assistance agencies to target cost-share and operator assistance programs, all efforts that would enable further ammonia reductions and avoid or reduce future regulatory costs. Specific objectives include:

1. Assess the current extent of BMP adoption among feedlot operations in Colorado, Iowa, Kansas and Nebraska using responses from an ammonia BMP survey.

2. Identify farm characteristics, demographic factors, economic factors, and environmental perceptions that influence feedlot operator adoption of individual ammonia BMPs in Colorado, Iowa, Kansas and Nebraska.
3. Recommend strategies to effectively target BMP adoption extension programs based on results from Objective Two.

1.4 Methodology

First, this study analyzed the survey responses to determine current levels of BMP adoption. Adoption of a practice was posed as a discrete choice; whether or not the feedlot employed this practice. In addition, the initial data analysis provided information on the environmental and economic perceptions of each BMP for the average producer.

Second, since the random variable of interest was a dichotomous choice (a producer chose to adopt or not adopt) the analysis employed discrete choice methods to evaluate adoption decisions. Economic perceptions relating to the specific BMP as well as producer and farm characteristics were hypothesized to impact adoption. Furthermore, discrete choice analysis enabled the estimation of the conditional probability of adoption given a set of farm and operator characteristics. Results detail the expected change in probability of adoption with a change in attribute. Examples of attributes include size of operation, investment capability and age of managing operator.

Last, findings from the discrete choice modeling will motivate recommendations for outreach professionals. Practices are suggested for certain classes of producers based on current adoption rates, and variables found to statistically influence adoption.

1.5 Data

This study used cross-sectional survey data to collect information on BMP adoption by feedlot operations. The survey requested basic production information (investment capabilities and revenue) as well as farm and operator demographic characteristics. The primary BMP information was provided by questions on specific BMP adoption, as well as economic and environmental perceptions pertaining to each BMP. The sample set for this questionnaire was selected from the National Agriculture Statistics Service list of feedlots for the states of Colorado, Kansas, Iowa, and Nebraska. After discarding non-applicable operations, this study presented data on 159 feeding operations. [1]

1.6 Contribution of Study

Ammonia emissions from feedlots are increasingly coming under public scrutiny, and the future of regulation depends upon the effectiveness of outreach to encourage voluntary BMP adoption. More effective outreach depends on understanding overall adoption levels, as well as constraints to BMP adoption, and the economic and demographic profile of adopting and non-adopting operations.

A large body of research exists documenting adoption of farm and crop BMPs targeted at improving water quality (Bauder *et al.*, 1997; Feather and Amachar, 1994; Nowak, 1983) as well as environmental perceptions driving voluntary adoption decisions (Gould *et al.*, 1989; Barbier, 1990; Govindasamy and Cochran, 1995; Westra and Olson, 1997; Soule, 2000).

[1] Dairy operations may also be a significant source of ammonia emissions. The survey was also targeted to dairies, but the response rate was too low to conduct a similar analysis.

Current research on adoption of manure management BMPs focuses primarily on practices to improve water quality (Rahelizatovo, 2002; Núñez, 2008). A 2008 study done by Núñez of four manure management practices (soil nutrient testing, manure nutrient testing, land application based on phosphorus need, and injection) for Missouri and Iowa producers found that off-farm income, location, perceived profitability and perceived complexity were significant factors in determining BMP adoption. Prior to this research, Rahelizatovo (2002) studied incentives for dairy manure management practices and found that adoption was highly influenced by farm and operator characteristics, environmental perceptions as well as producer attitudes. In particular, BMPs were often incompatible with profit-maximization goals. Educated and younger producers were most likely to implement BMPs, indicating that lack of knowledge and economic barriers most limited adoption of this set of BMPs.

However, to the knowledge of this researcher, no significant study to date has studied factors influencing adoption of ammonia BMPs. This is likely due to the relative lack of attention lent to ammonia and air quality BMPs in comparison with water contaminants from animal manure. Many of the same factors found to influence manure and crop BMPs may apply to this sample, but since the practices themselves vary substantially in capital and labor requirements, barriers and incentives will likely be unique and BMP-specific.

1.7 Organization of Thesis

The following chapter outlines the health and environmental consequences of ammonia emissions, the regulatory environment facing feedlots, as well as an overview of the BMP approach to reducing emissions. Chapter Three details the data collected to conduct the analysis as well as the methodology used to estimate factors determining BMP adoption. Chapter Four presents the summary statistics of surveyed operators as well as the results of the econometric models. Chapter Five summarizes and concludes, offering potential outreach policies, limitations of findings and future directions.

CHAPTER TWO

BACKGROUND

This chapter aims to further develop the problem statement described in Chapter One. The first section discusses ammonia agriculture emissions as an environmental and human health problem. The second section details the current regulatory regime and justifies a BMP approach. The third section describes BMPs and their ammonia reduction potential, while the fourth section summarizes.

2.1 Ammonia Agriculture Emissions

Although difficult to measure, animal agriculture is estimated to contribute 50-85% of total atmospheric ammonia (Battye *et al.*, 1994). Concentrated animal feeding operations (CAFOs) pose a particularly large risk of contamination as they concentrate animal's feed, manure, and urine in a small land area. Ammonia (NH3+) is produced when urea (the waste produced when the liver breaks down protein) in urine mixes with the enzyme urease, found in manure. Once the urine and manure has mixed, the ammonia is converted into a gas within two to ten hours (Muck, 1981). Once converted into a gas, atmospheric ammonia is harmful to health at high levels, emits a noxious odor, and contributes to the formation of fine particulate matter and subsequent nitrogen deposition, harming air quality and ecosystems.

Once in gaseous form, ammonia reacts particularly easily with other particles in the atmosphere, especially nitric and sulfuric acids produced from vehicles and industrial emissions to form fine particulate matter ($PM_{2.5}$). The small size of the fine particulate matter enables wind to carry it from rural areas to urban areas, where they build up in the atmosphere contributing to smog and respiratory problems (Marcillac *et al.*, 2007).

Heavy concentrations of atmospheric ammonia are harmful to human and livestock health, as well as ecosystem stability. Once gaseous ammonia is deposited through both wet and dry deposition processes, it leads to nitrogen loading wherever deposited. Ammonia is an important source of nitrogen for living systems, so excess nitrogen deposition can enhance the growth of certain species. This can increase the both vulnerability of other species relative to nutrient-tolerant species an increase overall ecosystem acidity. Imbalances often result as normal ecosystem processes shift.

The ecosystem of Rocky Mountain National Park is of particular concern in Colorado, and is more vulnerable than most ecosystems due its high altitude. Rocky Mountain National Park is characterized by shorter growing seasons and shallow soils, both which limit the ability of the ecosystem to absorb excess nitrogen. Furthermore, due to the shallow soil and short growing seasons, species are especially adapted for nitrogen-poor environments, rather than nitrogen-rich environments. A large body of research cited in the Rocky Mountain National Park Nitrogen Deposition Reduction Plan (CDPHE, 2007) documents ecosystem changes in the area, some of which include:

- Naturally occurring plant species are transitioning to nutrient-tolerant plant species.

- Chronically elevated levels of nitrate in surface waters are resulting in increased fish mortality.
- Increased levels of nitrogen in spruce tree chemistry, decreasing tree resistance to disease, insects, droughts, etc.
- A general ecosystem shift from alpine tundra plants and wildflowers to sedges and grasses.

Recent research has suggested that nitrogen levels are bringing this ecosystem to a tipping point which could take centuries to change (Bowman *et al.*, 2006).

2.2 Regulatory Environment

The Environmental Protection Agency (EPA) is the federal agency responsible for identifying environmental problems and implementing environmental laws passed by Congress by developing and enforcing regulations. The EPA defines pollution as either point or nonpoint. Point source pollution is defined as:

> "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture." (Section 502 (14) of the Clean Water Act (CWA) of 1987)

The EPA defines Concentrated Animal Feeding Operations (CAFOs) as any operation larger than 1,000 cattle or cow/calf pairs, or medium and small operations that meet pollution criteria. The EPA subjects all CAFOs to point source regulation. Nonpoint sources are defined as any other source of water pollution that does not meet the legal definition of a point source (EPA, 2000). Both the increasing size and animal density of CAFOs as well as geographic clustering of operations has led to a greater geographic concentration of pollutants (Kellogg *et al.*, 2000).

2.2.1 Non-Voluntary Regulations

Regulations are one potential approach to reduce CAFO ammonia emissions implemented by taxation or regulation of a polluting input or production process. A tax on a polluting input effectively increases the price of the input, reducing usage or requiring producers to switch to a less polluting input. Costs of a tax policy to farmers vary depending on their access to the substitute input and their dependence on the taxed input, which varies geographically. Studies have found that an input must be taxed at a higher rate than the desired percent reduction, indicating deadweight loss to society (Feather and Cooper, 1985).

As opposed to taxes, regulations require that operators employ a specific practice or set of practices, or ban the use of a polluting input. However, the cost and efficiency of a regulation can vary across operations depending on geographic and farm characteristics. Blanket regulations require costly technical assistance programs and high enforcement costs (Ribaudo *et al.,* 2003).

2.2.1.1 Regulations for Water Contamination

Cost and ease of regulating water contamination depends largely on whether the source of the pollution is point or nonpoint. The CWA initially excluded nonpoint pollution due to difficulty of regulation. In 1987 the CWA was amended to include nonpoint pollution, by establishing the Nonpoint Source Management Program (NPDES) which gives EPA the authority to provide grants, program guidance and technical support for state projects promoting nonpoint source management plans and other programs. Ultimately, the CWA places responsibility on individual states to control nonpoint pollution.

2.2.1.2 Regulations for Air Contamination

Currently, the air emissions produced by CAFOs (including ammonia emissions) are not regulated. Two possible venues could develop regulations that impact agricultural ammonia emissions. First, the Clean Air Act (CAA) regulates atmospheric emissions, and specifically $PM_{2.5}$ through the National Ambient Air Quality Standards (EPA, 1998). Since a large portion of $PM_{2.5}$ develops from ammonia, regulations aimed at reducing $PM_{2.5}$ concentrations could require reductions in ammonia emissions from animal operations. In 2006, the EPA updated their air quality standards, with designations to take effect in 2009 (EPA, 2006). From the date of designation, states have three years to develop an implementation plan. However, of the four-state region sampled in this research, only two counties in Iowa were found classified as partially non-attainment counties. NAAQS will not play an immediate role in reducing emissions negatively impacting the ecosystem of Rocky Mountain National Park.

Second, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), enables the EPA to respond to hazardous substances that risk public health. Section 309 of the Emergency Planning and Community Right-to-Know Act (EPCRA) requires large AFOs to report certain releases to local and state agencies.

The limit for ammonia is 100 lbs during a 24-hour period, which many operations meet or exceed. The EPA recently exempted animal feeding operations with fewer than 1000 cattle from reporting as required by CERCLA as of January 20, 2009 (EPA, 2008). The EPA stipulates that per the EPCRA, operations are still legally required to notify releases of hazardous substances above CERCLA thresholds and failure to do could result in enforcement (EPA, 2007).

2.2.1.3 Limitations of Current Federal Regulations

Despite making significant gains in water quality as a result of the CWA, the federal focus on water quality tends to overshadow the growing problem of air pollution from agriculture. Furthermore, some practices that target water pollution directly or indirectly exacerbate air pollution via ammonia emissions. In 2003, the CWA updated to require CAFOs to implement nutrient management strategies when applying manure spread to fields to minimize groundwater pollution. NPDES requires certain CAFOs to hold permits that specify an effluent limit in the production area and on the land that receives the manure. Due to the high cost of moving manure to fields, this policy incentivized producers to reduce the nitrogen content of manure by allowing it to volatize in lagoons, or simply applying it to the land without incorporating it into the soil- both practices which increase atmospheric ammonia emissions (USDA, 2005)

2.2.2 Voluntary Incentives

Voluntary incentives provide financial or technical assistance for adoption of a practice or set of practices that mitigate pollution. Financial incentives take the form of cost-sharing or incentive payments, methods that reduce costs and risk associated with adopting a new practice. Cost-sharing programs focus on covering a portion or all of the fixed costs of a new practice, and are often used if a practice has high installation or start-up costs. Incentives payments aim to reduce the risk of adopting a practice that may be profitable, but is unfamiliar to operators. Financial incentives can be costly to design and administer (Feather and Cooper, 1995).

Most efforts to reduce nonpoint pollution provide technical assistance and education to operators. Education efforts aim to increase awareness of the environmental benefit of adopting a practice, as well as potential profitability. Technical assistance can also lower initial costs associated with designing and implementing a practice. Feather and Cooper (1995) note that such programs are most appropriate for simple and profitable practices that require minor changes to the production process.

2.2.3 Colorado Regulations of Agriculture Emissions

Due to the prohibitive enforcement costs of regulations and the cost constraints they pose to operators, Colorado elected to promote the voluntary adoption of practices that reduce animal agriculture emissions. BMPs are recommended methods to prevent ammonia emissions while not compromising returns (Waskom, 1994). Voluntary adoption of BMPs not only could cut agricultural ammonia emissions by an estimated 60-70% but would improve public perception of the animal agriculture industry and help avoid future regulation (Powell, 2006).

2.3 Best Management Practices for Ammonia Emissions

Ammonia can be targeted at a variety of stages in the agricultural process, from the input stage (animal nutrition), up through storage and disposal of manure. The following section will briefly describe the stage at which each selected BMP occurs, and important chemical processes in order to understand the mechanism by which each BMP contributes to ammonia reduction. This study analyzes thirteen ammonia BMPs, described in a review done by Marcillac *et al.* (2007) of BMPs for agricultural air emissions. The BMPs are categorized as feeding, drylot or waste management BMPs.

2.3.1 Feeding

Feed management is often the most economical way to target ammonia emissions by reducing the amount of nitrogen excreted by the animals, and hence reducing the opportunity for ammonia volatization once waste has been excreted. Decreasing the percent excreted can be achieved by reducing the amount of crude protein fed to animals or increasing overall animal efficiency. Reducing crude protein is highly effective as it reduces the overall level of nitrogen excreted, reducing opportunities for volatilization. Since protein is the most expensive input into an animal's diet, reducing protein is cost-reducing and possibly profit-enhancing. Additionally, the practice of group feeding involves matching nutrient needs with the age, sex and production level of the animals, reducing the excretion of excess nitrogen. Efficient animals tend to excrete less nitrogen, though the relative gains are smaller compared with reducing protein. Multiple methods contribute to increasing animal efficiency, but using feed additives is the main method analyzed for the purposes of this study. The feeding BMPs addressed in this study include:

1. Measuring and adjusting dietary crude protein to meet animal needs.
2. Hiring a nutritionist.

3. Practicing group feeding.
4. Using feed additives.

2.3.2 Drylots

Drylots are the largest source of ammonia emissions in an animal operation. The most cost effective ammonia reduction strategies in drylots aim to discourage animals from congregating (and excreting) in few places or limiting the conditions that favor ammonia volatization (high temperatures, high pH, etc) of the drylot surface. Providing shade in the center of a drylot encourages cattle to move with the shade throughout the day, somewhat distributing the manure and reducing opportunities for volatilization. Applying water to drylot surfaces greatly reduces dust, reducing opportunity for ammonia to form $PM_{2.5}$, though there is also evidence of increased volatization from wet surfaces. Providing bedding containing carbon in drylot pens increasing absorption of ammonia. Frequent removal of manure to another storage location reduces exposed surface area, therefore, reducing the opportunity for ammonia volatization.

Furthermore, acidic surfaces slow down volatilization. Applying acidifier enables ammonia to exist as NH_4^+ which a non-volatile ammonium ion, whereas if it exists in basic conditions it exists as NH_3 gas. Although a cost-effective surface treatment appropriate for large operations has yet to be found, lab-tested treatments have been found to reduce emissions by between 62- 98%, though it should be noted that field application may be somewhat less effective (Shi *et al.,* 2001; DeLaune *et al.,* 2004).

The drylot BMPs applicable to this study are:

1. Providing shade in drylot pens.
2. Applying acidifier to drylot surface.
3. Applying water to drylot surface.
4. Providing bedding in drylot.
5. Removing manure.

2.3.3 Land Management

Last, ammonia contamination can be reduced at the manure application stage by reducing exposure time and implementing a nutrient management plan that can reduce nitrogen loss. Promptly incorporating manure into the soil reduces surface exposure time, decreasing time for the ammonia to volatize. A nutrient management plan which includes testing manure and soil for nutrients enables crop needs to be better matched with manure nutrient content, minimizing nutrient loss. Yearly soil testing can enable a producer to provide nutrients via manure when and where they are most in demand. Unlike previously discussed BMPs, the CWA often requires operations to have nutrient management plans including these practices. Manure application BMPs addressed in this study include:

1. Incorporating manure within 48 hours after application.
2. Testing manure, effluent, or compost for nutrients.
3. Performing a yearly soil test for cropland nutrients.

2.4 Summary

This section justified research objectives by presenting the environmental problem, as well as the limitations in the current regulatory regime to confront the problem. Ammonia emissions remain largely unaddressed by federal state policies, leaving the responsibility to individual states to manage ammonia regulations. Colorado is increasingly promoting a variety of BMPs to address ammonia emissions in various stages of the production process. The BMPs analyzed in this study were presented in the last section of this chapter. Ultimately, the environmental problem of ammonia emissions is a result of an economic problem stemming from the decision-making process at the farm level, particularly a lack of incentives that match the importance of the issue. Chapter Three describes a survey instrument that aims to collect data that will be used to better understand the BMP choices made by feedlot operators. Additionally, Chapter Three presents the economic theory that underlies the use of discrete choice models to explain the adoption decision.

CHAPTER THREE

DATA AND METHODOLOGY

This section presents the design, layout and response rate of the survey which provided the data for this analysis. Furthermore, this section details the theory underpinning the econometric methods chosen to explain BMP adoption decisions, the second objective of this study. The steps of the econometric process are laid out in the last section of this chapter.

3.1 Study Area

The survey was mailed to 1,998 dairies and feedlots, though this research will only analyze feedlot results. The sample set for this questionnaire was selected from the National Agriculture Statistics Service (NASS) list of feedlots for the states of Colorado, Kansas, Iowa, and Nebraska. The feedlot sample frame was limited to operations with more than fifty head. Sampling among states was stratified by NASS to adequately represent the size distribution of feedlots within each state.

3.2 Survey Design

A mail-out survey using the Dillman technique (Dillman, 1991) was prepared by an interdisciplinary team and reviewed by an advisory committee of feedlot owners, industry stakeholders, and technical experts. After review, the questionnaire was revised based on their recommendations and mailed during the fall of 2007.

Of the 203 returned surveys, 13 respondents returned blank surveys indicating that they were either retired, did not own a dairy or feedlot, or did not want to participate. The remaining 31 surveys were completed by dairy operations, thus do not apply to the feedlot analysis. Of the remaining 169 surveys, ten surveys were determined to be cow-calf operations and hence, not applicable. One hundred and fifty nine surveys were finally used in this feedlot analysis making for an overall response rate for dairies and feedlots combined of 7.9%. The original sample stratification of dairies and feedlots is unknown, so the exact response rate pertaining to the feedlot analysis could be larger or smaller than 7.9%, depending on how closely the respondent stratification matches the sample stratification.

3.3 Data Collected

The survey was divided into six sections, and the following paragraphs will review the information and the objective of the information requested of the respondent in each section. The full survey can be found in Appendix E.

3.3.1 Basic Production Information

The first section of the survey requested that the respondent indicate the type and size of the operation, the state in which it is located and a variety of operation characteristics. The survey asked respondents to indicate the number of animals in various categories (dairy cows, beef cows/ calf pair, feeder, other livestock, etc.). The total number of animals was found by summing only the number of background calves and feeder livestock. Additionally, the survey asked a few questions meant to gauge the land area of the operation; specifically, respondents were asked to indicate both the area of the livestock facility and the amount of overall cropland. However, responses relating to the area of the livestock facility indicated confusion with area of cropland, so only cropland area data was used in the statistical analysis. Additionally, the survey requested the percentage of the cropland that was owned.

This section also contained a few questions meant to provide the researcher with a management profile for the operation including years of experience, and what percent of overall revenue provided by the feedlot, which aimed to gauge the level household income diversification. Expectations may influence BMP adoption, so respondents were asked if they planned to increase the operation scale in terms of both number of animals and physical infrastructure.

3.3.2 Best Management Practices

The section of the survey that focused on BMPs asked operators to indicate whether or not they adopt each one of the practices discussed in Chapter Two, as well as indicate on a Likert scale of one to five (1-strongly disagree and 5-strongly agree) whether they agreed with the following statements for each BMP:

- This practice is profitable.
- This practice requires outside technical assistance.
- This practice is expensive.

These questions were intended to gauge producer perceptions of profitability, cost, and technical assistance, respectively. Furthermore, producers were asked to respond either ‘yes’ or ‘no’ to separate statements that each BMP safeguards air or water quality.

3.3.3 Manure Management System

This section asked a variety of questions relating to the operator's primary manure storage and treatment system. For each type of manure management system (lagoon, solid separation, compost, stockpile, runoff pond and pit) the survey requested more detailed information pertaining to that system. This information was requested to assist outreach personnel in better understanding the disposal systems in use, and was not used in determining BMP adoption in this thesis. Future research could use this information when forecasting potential adoption by manure system type

3.3.4 Optional Demographic Information

Since adoption of BMP may depend on a producer's financial capabilities, age and level of education, this last section contained related questions. Information that summarizes respondents' demographics was useful in providing a general description of respondents. However, the survey marked this section as optional, so overall response rate was low. In general, producers were far more willing to disclose their age and education than profitability and investment capabilities.

3.4 Best Management Practice Adoption

Economics studies how individuals make decisions when faced with limited resources that can be allocated towards competing uses. This section presents the underlying theory from which economic analysis often begins, and then extends this logic to the model that was used to evaluate producer adoption decisions.

3.4.1 Rational Choice Theory

Economists frequently use Rational Choice Theory to model and explain behavior. Rational Choice Theory fundamentally assumes that the decision an individual makes best enables them to meet their objectives, considering all relevant factors based on the following axioms of rational behavior:

1. Completeness: when faced with any two situations, an individual either prefers A to B, vice versa, or is indifferent.
2. Transitivity: if an individual prefers A to B and prefers B to C then they must also prefer A to C.
3. Continuity: if an individual prefers A to B then situations "close" to A are also preferred to B.

Individuals can rank all possible alternatives in terms of their underlying preferences among goods. It is assumed that individuals can rank consumer goods such as cars, electronics, etc., or activities such as recreation and leisure. Preference rankings can be represented by utility, so that when making a decision, consumers weigh whether a decision will bring them added utility or cost them utility (Nicholson, 2005). For this study, an operator is assumed to derive utility or disutility by adopting a BMP.

3.4.2 Optimization Behavior

Economists often represent individual preferences by a utility function. Preferences are assumed to obey seven properties in order to be able to map utility. The consumer's utility function is represented by $U = U(x, y)$, where the function $U(x,y)$ assigns a number to any given set of values for x and y. Utility functions are generally assumed to be locally non-satiated. If this assumption holds, they are strictly monotonic, that is, more of *x* (or *y*) is always preferred to less. Also, utility functions exhibit diminishing marginal utility as long as preferences obey particular underlying assumptions, as an individual gains more of *x*, the additional per-unit utility gained decreases (Nicholson, 2005).

By representing utility mathematically, individual decision-making becomes a problem of optimizing utility subject to constraints. Budget or income often defines the constraint on decision-making, but a stock of a natural resource can also act as a constraint. Solving this optimization problem results in a decision rule showing how behavior changes as key parameters or variables shift (i.e. income). Optimizing utility plays a key role in modeling producer BMP adoption decisions.

3.5 Estimation Procedure

BMP adoption implies a discrete choice between adopting the BMP and forgoing its use. Economics places the choice within a utility maximization context, and empirical methods allow for the probability of adoption to be estimated using discrete choice methods. The research in this thesis uses two specific discrete choice methods: binary logit regression and multivariate probit, each of which is discussed in the following sections.

3.5.1. Discrete Choice Modeling

Discrete choice modeling represents the class of models designed to analyze decision-making for an individual who faces a discrete number of choices. Qualitative choice models explain decisions where the dependent variable is qualitative, rather than quantitative in nature (*e.g*. yes, no, maybe). Binary choice models are specific types of qualitative choice models, where the dependent variable is binary, typically representing a yes/no decision (Greene, 2000).

Conducting Ordinary Least Squares (OLS) on binary dependent variables results in a Linear Probability Model (LPM). LPMs predict the probability of events occurring assuming the independent variables are linearly related to the dependent variable. However, since LPMs assume a continuous dependent variable, they permit negative probabilities and probabilities greater than one. Furthermore, the LPM violates OLS assumptions of homoskedastic errors and normally distributed errors (Gujarati, 2002). This calls for an alternative estimation procedure, namely one that relies on maximizing utility.

When choosing whether to adopt a BMP, an operator faces two choices: to adopt the practice, or to not adopt the practice. The random utility model underlies binary choice models, where the operator will maximize their expected utility from the adoption of the BMPs according to:

(3.1)

$$U_i^1 = \overline{U}_i^1 + \varepsilon^1 = \beta_{1i}^1\gamma + \beta_{2i}^1\delta + \beta_{3i}^1\omega + \varepsilon^1$$

$$U_i^0 = \overline{U}_i^0 + \varepsilon^0 = \beta_{1i}^0\gamma + \beta_{2i}^0\delta + \beta_{3i}^0\omega + \varepsilon^0$$

Where U_i^1 represents the utility derived by individual *i* from choosing the BMP, and U_i^0 represents utility derived by individual *i* from <u>not</u> choosing the BMP, γ represents a vector of perceptions variables held by individual *i* regarding the BMP, δ represents a vector of economic and operator characteristics for individual i, ω represents a vector of farm characteristics of the operation of individual i and ε represents the disturbance.

The latent (unobservable) variable (y_i) can be represented by the explanatory variables according to equation (3.1). The probability that individual i would choose to adopt the BMP j (y_i =1) or not adopt the BMP (y_i =0) is represented by:

$$(3.2) \qquad p_{ij} = prob(y_i \mid Z) = prob\ (y_i^* > 0) = prob\ (\varepsilon^* > -\beta' x_i)$$

If the index of explanatory variables (Z) exceeds a critical value, then the latent variable exceeds zero, and the individual will adopt the BMP. Equations (3.1) and (3.2) reveal the latent variable (y_i^*) defined as

$$(3.3) \qquad y_i^* = U_i^1 - U_i^0$$

$$= (\beta_{1i}^1 - \beta_{1i}^0)\gamma + (\beta_{2i}^1 - \beta_{2i}^0)\delta + (\beta_{3i}^1 - \beta_{3i}^0)\omega + (\varepsilon^1 - \varepsilon^0)$$

$$= \beta' x_i + \varepsilon^*$$

Where $\beta' x_i + \varepsilon^*$ is a linear function with explanatory variables (x_i), unknown parameters (β) and statistical error (ε^*) (Madalla, 1983).

The latent variable is linked to the binary variable (adopt /don't adopt) collected from survey data:

$$(3.4) \qquad y_i = 1\ if\ y_i^* > 0 \quad \textbf{or}$$

$$y_i = 0\ if\ y_i^* \leq 0$$

3.5.2 Univariate Logit Model

Modeling binary choices can be undertaken using either the probit model or the logit model, depending on whether standard normal or a logistic distribution (respectively) is assumed for the error term (ε^*). Both distributions are symmetrically bell shaped and have a mean of zero. The logistic distribution is similar to the normal except for that it is heavier in the tails, so it will give larger probabilities when $\beta x'$ is either large or small. Either one enables the researcher to compute the probability that Y=1 (adoption of a practice) given the set of explanatory variables. As it is difficult to justify one or the other on theoretical grounds, the logistic distribution will be used for the univariate case in this research, due to its mathematical convenience (Greene, 2000).

The probability that each producer adopts the BMP can be represented as follows:

(3.5) $$P_i = f(Z)$$

where P_i = probability that individual i adopts the practice j, and

(3.6) $$Z_i = f(\beta_0 + \beta_1 \gamma_{ij} + \beta_2 \delta_i + \beta_3 \omega_i + \varepsilon) = \beta' x$$

Where γ = vector of perceptions variables held by individual i regarding practice j, δ = vector of economic and operator characteristics for individual i and ω = vector of farm characteristics of the operation of individual i.

The probability of adopting a BMP can be represented as:

(3.7) $$p_i = prob(Y = 1) = f(Z) = \frac{e^z}{1+e^z} = \frac{e^{\beta\prime x}}{1+e^{\beta\prime x}} = \emptyset(\beta' x)$$

Equation (3.7) represents the logistic distribution function, and $\emptyset$ is used to represent the logistic cumulative distribution function. The following probability model becomes a regression:

(3.8) $$E(y) = 0 - [1 - F(\beta' x)] + 1[\emptyset\,(\beta' x)] = \emptyset\,(\beta' x)$$

3.5.3 Marginal Effects

Due to the nonlinearity of the binary choice model, interpreting the impact of a parameter on the dependent variable is less straightforward than a linear regression. Binary choice models rely on calculating the marginal effect which is the partial change in the probability of adoption resulting from a change in the value of an independent variable. The marginal effect is calculated by partially differentiating the expression of probability with respect to each independent variable.

In general, marginal probabilities [$\frac{\partial E[y]}{\partial x}$] are calculated as follows (Greene, 2000)

(3.9) $$\frac{\partial E[y]}{\partial x} = \frac{dF(\beta' x)}{d(\beta' x)} * \beta$$

In the case of the logistic distribution:

(3.10) $$\frac{d\emptyset(\beta' x)}{d(\beta' x)} = \frac{e^{\beta' x}}{\left(1 + e^{\beta' x}\right)^2} = \emptyset(\beta' x)(1 - \emptyset(\beta' x))$$

Logit marginal probabilities are thus:

$$(3.11) \qquad \frac{\partial E[y]}{\partial x} = \emptyset(\ \beta' x\ )(1 - \emptyset(\ \beta' x\ )\beta$$

Usually marginal probabilities are calculated using the means of the regressors, though this is inappropriate when reporting dummy variables since this value would not correspond to an observed value. In this research, the average value of the dummy variable across observations was rounded to zero or one in order to calculate the marginal probabilities.

3.5.4 Multivariate Probit Model

The bivariate and multivariate probit models are multiple-equation extensions of the generalized probit model. This extension includes more than one equation and allows for correlation of error terms among equations (Green 2000). The general equation for the multiple-equation model would be:

$$(3.12) \qquad y_1^* = \beta' x + \varepsilon_1 \qquad y_1 = 1\ if\ y_1^* > 0, 0\ otherwise$$

$$y_2^* = \beta' x + \varepsilon_2 \qquad y_2 = 1\ if\ y_2^* > 0, 0\ otherwise$$

$$y_m^* = \beta' x + \varepsilon_3 \qquad y_m = 1\ if\ y_m^* > 0, 0\ otherwise$$

Where $\mathrm{E}(\varepsilon_1) = \mathrm{E}(\varepsilon_2) = \mathrm{E}(\varepsilon_3) = 0$ and $\mathrm{Var}(\varepsilon_1) = \mathrm{Var}(\varepsilon_2) = \mathrm{Var}(\varepsilon_3) = 1$

Error terms have a multivariate normal distribution with mean vector 0 and a covariance matrix with diagonal elements equal to 1.

The probabilities that enter into the likelihood function would be:

$$\text{(3.13)} \qquad \text{Prob} \quad \frac{Y_{i1,}Y_{i2,}Y_{im}}{x_{i1,}x_{i2,}x_{im}} = \text{MVN(TZ, TRT)}$$

Where MVN is the multivariate normal distribution; T is a diagonal matrix with element $t_m = 2Y_{m,} - 1$; Z= a vector with elements $z_{iM} = \beta_M{}' x_{iM}$ and R= correlation matrix of the error terms and m= 1,2….M.

3.6 Variables

The following subsections present independent and dependent variables populating Equation 3.8 (the univariate logit) and Equation 3.12 (the multivariate probit). Most of the section is devoted to theory supporting the inclusion of each explanatory variable used in the regression analysis.

3.6.1 Binary Dependent Variable

The binary dependent variable is defined as adoption or non-adoption of a specific BMP. Each BMP represented a unique model where the dependent BMP was regressed on the explanatory variables. That is, for the univariate analysis, there were thirteen unique logit equations developed according to the discussion in Section 3.5.2. BMPs were divided into three categories: feeding BMPs, drylot BMPs and land management, where correlation was testing among BMPs of each category. BMPs for the multivariate estimation. The BMPs were stratified as follows, where the name of the dependant variable is listed in parenthesis.

Feeding BMPs:

1. Measure dietary crude protein to meet animal needs (PROTEIN)
2. Hire a nutritionist to formulate rations (NUTRITION)
3. Practice group feeding (GROUP)
4. Use feed additives (ADD)

Drylot BMPs:

1. Remove manure more than four times per year (CLEAN)
2. Provide bedding (i.e. straw) in drylot pens (BED)
3. Collect runoff water from buildings and pens (RUNOFF)
4. Apply water to the surface of drylot pens (SURFACE)
5. Apply an acidifier to drylot surfaces (ACID)
6. Provide shade in drylot pens (SHADE)

Land Management BMPs:

1. Incorporate manure within 48 hours of application (INCORPORATE)
2. Test manure, effluent, or compost for nutrients (TEST)
3. Perform a yearly soil test for cropland nutrients (SOIL)

3.6.2 Independent Variables

The factors hypothesized to impact BMP adoption include operation characteristics, operator characteristics and attitudinal variables. These factors are listed in Table 3.2. Each model representing an individual BMP included all of these explanatory variables. The following section describes each independent variable as well as theory supporting each variable's inclusion in the model.

Table 3.1 Explanatory Variables Included in Analysis

Variable	Description
Operation Variables	
SIZE	Number of cattle
CROP	Acres of cropland
STATE	Dummy: 0= Colorado, 1= other state
REVENUE	Percent revenue kept as profit
INVEST	Dollars
DIVERSE	Percent revenue from feedlot
OWN	Percent of cropland owned by respondent
Operator Variables	
AGE	Years
EDUC	Years of education starting from 1st grade
FUTURE	Dummy: 0= invested, 1= divested
EXPER	Number of years managing operation
Attitudinal Characteristics	
PROFIT[a]	Perception of profitability of BMP from 1-5
COST	Perception of cost of BMP from 1-5
TECH	Perception of technical requirement of BMP from 1-5
WATER	Perception of benefiting water quality: Yes=1, No=0
AIR	Perception of benefiting air quality: Yes=1, No=0

[a] Perceptions were gauged using a Likert ranking where 1=strongly disagree with the perception, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

The survey questions that provide the information for OWN, EDUC, REVENUE, DIVERSE and INVEST asked that respondents select the appropriate category that generally began at zero and rose incrementally- providing from eight to ten options. Specific questions can be found in the survey in Appendix E.

3.6.2.1 Operation Variables

Operation characteristics were hypothesized to play an important role in determining BMP adoption. Size of operation (SIZE), measured in terms of head of cattle is hypothesized to positively influence adoption. Larger operations may be more motivated to ado pt certain BMPs simply as a result of the magnitude of the waste generated by the operation. Their disproportionate contribution to the waste problem may, in turn, heighten their sense of responsibility to manage waste to avoid regulation.

In the Rahelizatovo study, larger operations were more likely to adopt even non-capital intensive practices (Rahelizatovo, 2002). Generally, this trend can be attributed to a greater ability of large operations to spread high fixed costs over a greater number of production units. Also, larger operations tend to be less diversified, enabling them to focus their managerial and labor capacity more intensively.

Cropland (CROP), a continuous variable, measured in number of acres, was expected to have a positive impact on BMP adoption. Research has shown increasing marginal costs of applying manure as cropland increases (USDA, 2005).

Location was defined by a dummy (STATE) where zero represents Colorado and one represents a non-Colorado state (Kansas, Nebraska or Iowa). The possibility of regulation arose from concerns about the ecosystem of Rocky Mountain National Park in Colorado, so Colorado and neighboring state feedlots were the focus of this study. Hence, a positive and significant state variable would indicate that feedlots outside of Colorado are more likely to adopt a BMP. Climactic conditions, regulatory regimes and level of enforcement may also contribute to different adoption levels among states. If initial testing found STATE significant, further testing included dummy variables for three of the four states. A Colorado dummy was excluded, which enabled the other variables to be interpreted relative to Colorado.

The degree to which an operation diversified (DIVERSE) outside of the feedlot was measured by the percentage of overall revenue that was not generated from the feedlot. Diversified operations may have less incentive to adopt BMPs as managerial capacity is divided between the feedlot operation and other revenue-generating activities. Diverting further resources from the competing activity would involve a potential opportunity cost above and beyond that of a less diversified operation. DIVERSE was a categorical variable (from 0-100% in increments of ten percent), where each producer was assigned the average value of the selected category.

Overall cost efficiency of the operation (REVENUE) was measured as the ratio of profit over revenue multiplied by operation output. More specifically, respondents were asked to indicate the amount of profit captured from each dollar of revenue (options ranging from 1 to 32 cents on each dollar). Operations with a larger profit margin would be expected to be better placed to adopt BMPs due to having access to the financial capital to invest in a BMP. Furthermore, larger profit margins likely indicate higher managerial capabilities, which may indicate a greater willingness and ability to adopt new practices. REVENUE, a categorical variable, increased in increments of ten percent. The mean of each category provided the value entered into the model for each individual.

The variable INVEST described the amount of cash funds held by the operation for investment as a down payment on outright purchase. The variable INVEST was expected to have a positive impact on adoption, as an operation with capital to invest would be more able to meet the financial requirements of a new technology. INVEST was defined by increasing dollar increments (e.g. $10,001-$25,000), where the mean of each category provided the value entered into the model.

Ownership of cropland (OWN) was hypothesized to be important for land management BMPs, which apply to cropland. Owning cropland was hypothesized to increase the probability of adopting land management BMPs, as operators will directly benefit from application. Hoag, Lacy and Davis (2004) found that cattle ownership increased the probability of manure use on cropland as adoption was linked to both supply of manure and the demand from cropland.

3.6.2.2 Operator Variables

The variables age (AGE) and future plans (FUTURE) attempted to fully account for the degree to which the operator discounts the future and/or may be inclined to incorporate a new practice into their planning horizon. Younger operators have a lower discount rate and a longer planning horizon to reap potential profits, which may increase their probability of adopting a BMP; this trend was found in a study on manure management practices in the Louisiana dairy industry by Rahelizatovo (2002). On the other hand, older operators that plan to bequest an operation may have an incentive to preserve the environment for future generations.

The FUTURE variable assigned a value of zero for operators that remained vested in the future and a value of one for operators that were divested from the future. The information for this value comes from the series of questions asking whether or not they plan to invest in land, buildings or animals, and whether they plan to retire. An operator was labeled as ‘vested,’ if they either did NOT plan to retire, invest in land, new buildings or increase the number of livestock within the next five years, and are considered divested if they plan to retire, or and do not plan to increase buildings, land or livestock within five years. Including this variable controlled for older operators who remain invested in the operation. If FUTURE was found significant, further testing includes dummy variables for the components that make up this index.

Level of education (EDUC), found significant in the Rahelizatovo (2002) study, was defined as number of years of education beginning from 1st grade. If education improves managerial capabilities and ability to acquire new skills, higher education may lead to higher BMP adoption. Rahelizatovo (2002) found educational attainment to positively influence BMP adoption, attributing it to a greater capacity to access information and understand the pros and cons of various practices. When tabulating the data an individual reporting a high school degree was assigned a value of twelve (for twelve years), community college garnered an additional two years, a bachelors degree and additional four years, and post graduate and additional seven years (averaging standard timeline for a masters and a PhD program of two and four years, respectively).

Number of years managing the operation (EXPER) measures an industry-specific knowledge that was not necessarily obtained through formal schooling. Like education, experience enables producers to better understand the trade-offs of adopting a specific BMP.

3.6.2.3 Attitudinal Variables

Last, each model included five additional variables describing operator perceptions of each BMP, in line with previous findings that economic and environmental perceptions tend to influence BMP adoption. Profitability perceptions (PROFIT), cost perceptions (COST) and perceptions of outside technological requirements (TECH) defined economically-related perceptions, while air quality impact (AIR) and water quality impact (WATER) defined the environmentally-related perceptions. The TECH variable was hypothesized to lead to a similar outcome as the “complexity of technology” variable, which was found to negatively impact adoption in the study done by Núñez (2008).

Economic perceptions of a BMP were expected to highly influence adoption. A producer that perceived a practice to be unprofitable, costly and/ or requiring outside technical assistance would not be likely to adopt a voluntary practice; the practice would be perceived as having a high opportunity cost in terms of the additional labor or capital input. If the practice was perceived as unprofitable then the net effect would be to decrease profit margins, decreasing the likelihood of adoption by a profit-maximizing producer.

Núñez (2008) some found environmental perceptions to be significant in determining adoption. However, feedlot operators likely hold environmental perceptions relating to both air and water quality. Historically, regulations have focused on improving water quality and the perception that an ammonia BMP negatively impacts water quality would likely be linked to reduced adoption, even if it does reduce ammonia emissions. The manure BMPs are often part of an operation’s Nutrient Management Plan, as stipulated by the Clean Water Act. Perceptions of impact on water quality are expected to positively impact adoption of these BMPs.

3.7 Steps in the Empirical Analysis

In summary, the empirical analysis included the following steps:

1. Calculate summary statistics.
2. Develop the theory motivating inclusion of explanatory variables.
3. Run a single-equation logit analysis on BMP surveyed

4. Calculate marginal probabilities.

5. Reduce explanatory variables for inclusion in multivariate analysis.

6. Conduct multivariate analysis on three categories of practices.

7. Calculate probability of adoption for various scenarios.

The empirical results from this process are presented in Chapter Four. Chapter Five synthesizes the results in the context of the original research objectives.

CHAPTER FOUR

DESCRIPTIVE STATISTICS AND RESULTS

Chapter Four aimed to apply an empirical methodology to the analytical adoption framework described in Chapter Three. The empirical estimates of conditional probabilities will help accomplish research Objectives One and Two, namely, to identify barriers to BMP adoption. Moreover, these results aim to guide an outreach education strategy for ammonia BMP adoption. To better understand the underlying data and gain inference among regression results, descriptive statistics are presented for the data in the following section.

Two types of regressions were conducted: an initial exploratory phase (Phase I) and a phase of refined models (Phase II) using information from select models in Phase I. An additional empirical method, multivariate probit, was implemented to test the possibility of correlation among adoption decisions. The multivariate probit analysis follows Phase I and II.

4.1 Descriptive Statistics

The survey requested information on operation characteristics and operator demographics as well as perceptions of thirteen ammonia BMPs. Table 4.1 names, describes and provides units for each of the operator and operation variables, while subsection 4.1.1 presents summary statistics for these variables.

Table 4.1 Description of Operation and Operator Variables

Variable	Description	Unit
DIVERSE	Farm diversification	percent farm revenue
INVEST	Capital availability	dollars/year
REVENUE	Profit kept from revenue	percent revenue kept as profit
EDUC	Level of Education	years education beyond 1st grade
AGE	Age	years
FUTURE	Growth Plans	0, 1[a]
STATE	State Location	0,1[b]
SIZE	Operation size	number of cows
CROP	Cropland	acres
OWN	Land Tenure	percent cropland owned
EXPER	Experience	years managing livestock

[a]1= operator does not plan to increase livestock, invest in buildings or land or does plan to retire within next five years; [b]1= operation not located in Colorado, i.e. located in Iowa, Kansas, Nebraska

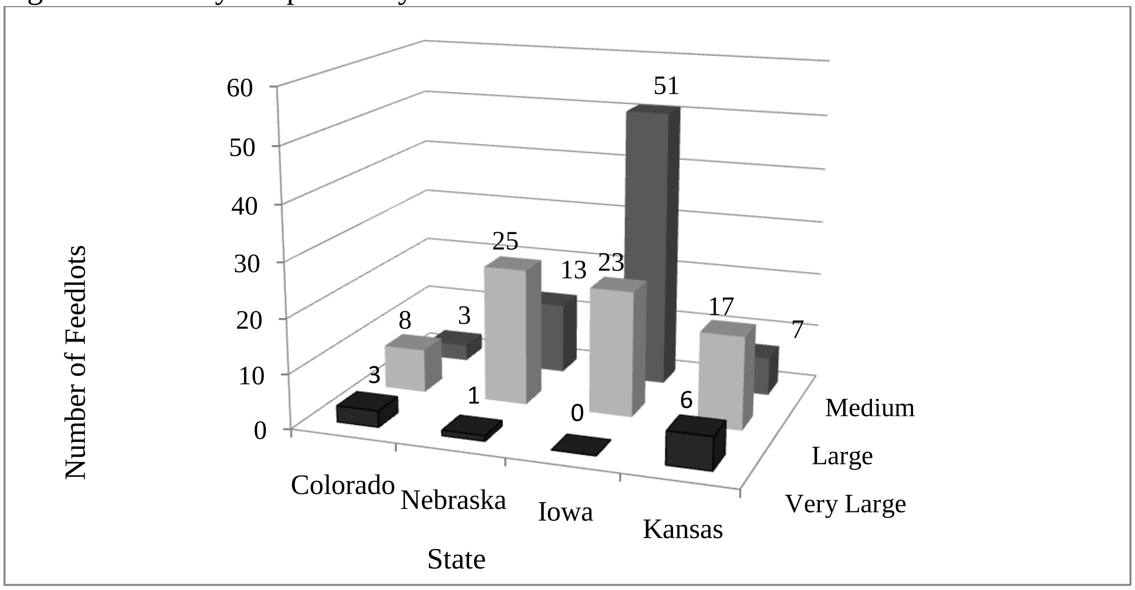
Section 4.1.2 discusses summary statistics for each of the BMPs as well as the BMP-specific perception variables (cost, technology, profit, air quality benefit and water quality benefit).

4.1.1 Operation and Operator Characteristics

Small operations with less than fifty head were not included in this study; therefore, when discussing descriptive statistics, feedlots will be referred to as medium, large and very large. Overall, 76 feedlots had less than 1,000 animals, 73 had between 1,000 and 31,999 and 10 had more than 32,000 animals. One operation with 120,000 cattle responded.

Questionnaires were sent out to feedlots in four states: Colorado, Nebraska, Iowa, and Kansas. The number of surveys sent out was stratified by the overall number of operations in the state. Nearly half (47%) of the feedlot responses came from operations located in Iowa, 25% from Nebraska, and 19% from Kansas. Fourteen operations (nine percent of the returned surveys) were located in Colorado, though Colorado had a larger proportion of large and extra-large operations than other states. Figure 4.1 shows the distribution of feedlot responses by state and size.

Figure 4.1 Survey Responses by Feedlot State and Size



Feedlot operators received an average of 58% of their revenue from the feedlot, indicating that for the average operation, the feedlot provided the primary, but not the sole, stream of revenue. The average operation reported keeping eight percent of revenue as profit. Very large feedlots reported keeping an average of 10% of revenue as profit, indicating some degree of economies of scale for feedlots. However these statistics may exhibit a selection bias as almost two-thirds of feedlot respondents either did not know or chose not to reveal this number. In terms of investment capabilities, a quarter of the feedlot respondents had $10,000-20,000 cash available for investment and nearly a quarter had $25,000-50,000 available. Around one-tenth of operators had $50,000-100,000 available and around one-tenth had no funds available.

Respondents were asked a variety of questions relating to how they expected their operation to change in the next five years, which gauged the degree to which an operation was vested in the future, and hence, likely to employ a new practice or technology. Figure 4.2 presents the 'yes' and 'no' responses for each question. An operator was considered 'vested,' if they either did NOT plan to retire, or did plan to invest in land, new buildings or increase the number of livestock within the next five years, and were considered divested if they planned to retire, or did not plan to increase buildings, land or livestock within five years. Defined as such, 87% of respondents remained vested in the future in one of the above categories. Nineteen percent of respondents planned to retire within the next five years.

Figure 4.2 Respondent Plans for Future of Operation

	Plan	Responses, by Question (n=159)	
		Yes	No
5 Years	Increase Livestock	43	56
	Decrease Livestock	10	103
	Invest in Buildings	63	51
	Increase Land	49	34
	Retire	15	102
5-15 Years	Increase Livestock	29	46
	Decrease Livestock	13	70
	Invest in Buildings	40	40
	Increase Land	44	27
	Retire	55	51

The average operator was 52 years old and had been managing their operation for 31 years. On average, medium feedlot operators had been operating their feedlot for the longest, while operations with over 30,000 had the lowest average managing years. In terms of education, feedlot owners most often had a high school degree or a bachelor's degree from a four-year university, averaging to a little over fourteen years of schooling.

Table 4.2 provides the summary statistics for each of these variables across the survey sample.

Table 4.2 Summary Statistics for Operation and Operator Variables

Variable	Mean	St. Dev	Max	Min	Kurtosis	Skewness
DIVERSE	69.1	21.0	85	4.5	-0.3	-1.0
INVEST	61,334	105,648	500,000	0	10.8	3.2
REVENUE	9.4	6.9	33	0	0.7	0.8
EDUC	14.1	0.2	17	10	-1.5	0.1
AGE	52.1	12.5	80	6	0.6	-0.3
FUTURE	0.2	.4	1	0	0.6	1.6
STATE	.89	.3	1	0	5.2	-2.6
SIZE	6,504	16,203	120,000	50	21.1	4.2
CROP	1,979	2,874	16,250	0	11.5	3.3
OWN	64.9	33.3	100	0	-1.0	-0.5
EXPER	30.7	12.1	61	3.5	.02	.04

4.1.2 Adoption Rates and Perceptions of BMPs

The main purpose of the survey lies in the information obtained about the adoption and perceptions regarding thirteen ammonia BMPs. Survey respondents were asked to rate various practices relating to the economic feasibility of a practice as well as whether the practice helped safeguard air or water quality. Table 4.3 ranks adoption levels of the thirteen BMPs. The practices were ranked based on the number that responded ‘yes’ to implementing each BMP. The percent of respondents that adopt/do not adopt later influences the explanatory power of the regression models. Variation among the yes/no response provides the models with more information on the underlying decision. Outliers, such as ACID and ADD, which were adopted by 3% and 4% of the sample, respectively, do not provide the model with sufficient information to make statistically sound inferences regarding the less common decision.

Table 4.3 Ammonia BMPs Currently Implemented by Survey Respondents

BMP	Adoption Rate
Use feed additives (ADD)	96%
Measure and adjust crude protein to meet animal needs (PROTEIN)	93%
Practice group feeding (group by age, sex, etc) (GROUP)	88%
Perform yearly soil test for cropland nutrients (SOIL)	78%
Hire a nutritionist to formulate rations (NUTRITION)	77%
Collect runoff water from buildings and pens (RUNOFF)	67%
Remove manure more than four times per year (CLEAN)	60%
Test manure, effluent, or compost for nutrients (TEST)	59%
Provide bedding in drylot pens (BED)	52%
Incorporate manure within 48 hours after application (INCORP)	42%
Provide shade in drylot pens (SHADE)	34%
Apply water to the surface of drylot pens (WATER)	28%
Apply an acidifier to the surface of drylot pens (ACID)	3%

Respondents were asked whether they considered a practice profitable, costly, or requiring outside technical assistance, using a Likert scale of one to five. For profitability, a five indicated they strongly agreed that the practice was profitable and a one indicated they strongly disagreed that the practice was profitable. For technical assistance, a five indicated they strongly agreed that implementing the practice depended on outside assistance and a one indicated they strongly disagreed the practice required technical assistance. For cost, a five indicated they strongly agreed that the practice was costly and a one indicated they strongly disagreed that the practice was costly.

With the exception of ACID and SURFACE, most of the practices were viewed as profit-neutral or profitable. Six of the practices were not considered to require outside technical assistance, while the remaining practices were perceived to require varying degrees of outside technical assistance. However, only two practices (PROTEIN and GROUP) were considered cost-reducing.

Respondents were asked to respond ‘yes,’ or ‘no’ to whether they believed a BMP safeguarded air or water quality. Table 4.4 indicated average operator response to each of the perception questions.

Table 4.4 Summary of Perception Variables for Each Ammonia BMP

BMP	Economic Perceptions [a]			Environmental Perceptions [b]	
	Profitable	Technical Assistance	Cost	Safeguard Air	Safeguard Water
PROTEIN	4.4	4.0	2.6	34%	51%
NUTRITION	4.1	4.2	3.1	32%	40%
ADD	4.3	3.7	3.2	28%	32%
GROUP	4.1	2.1	2.1	16%	10%
SHADE	3.4	2.2	3.4	24%	18%
SURFACE	2.9	2.1	3.4	62%	22%
ACID	2.5	3.0	3.4	26%	22%
CLEAN	3.7	2.1	3.5	68%	69%
BED	3.2	1.9	3.8	33%	36%
RUNOFF	3.0	3.2	3.9	40%	85%
INCORPORATE	3.4	2.2	3.5	67%	71%
TEST	3.8	4.0	3.4	41%	72%
SOIL	4.0	4.2	3.5	34%	69%

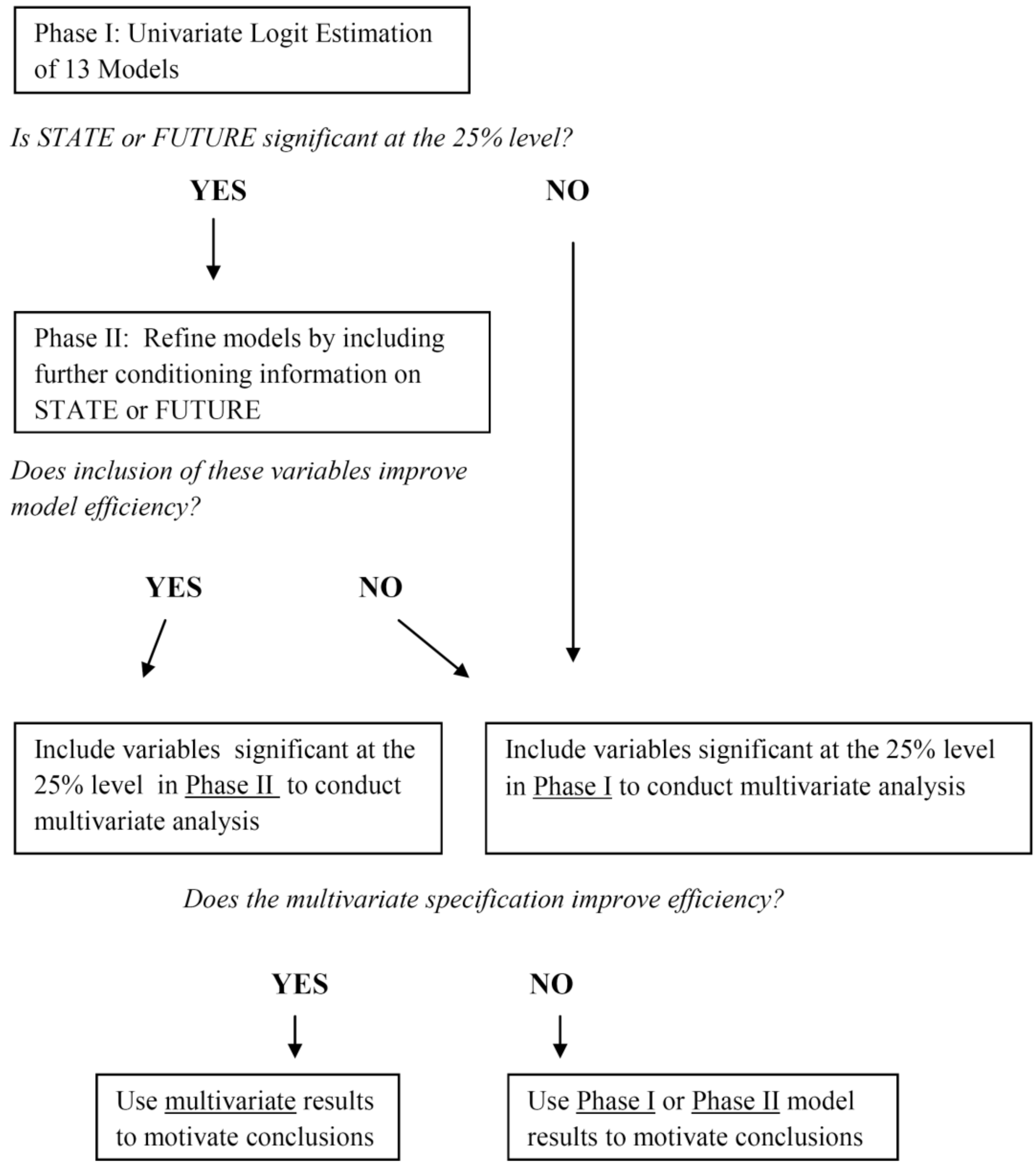
[a] Economic perceptions measured on a Likert scale of 1-5 where a 5 indicates agreement (1 indicates disagreement) with the following statements: this practice is profitable/this practice requires outside technical assistance/this practice is costly; [b] Respondent asked whether or not they agree that the specific practice safeguards air/water quality.

4.2 Empirical Framework

The first step involved estimating a single equation logit model including all fifteen variables hypothesized to impact adoption, for each of the thirteen BMPs. This phase was considered exploratory in order to provide direction for refined models. The second phase aimed to further explore the index variables STATE and FUTURE for which the survey provided further conditioning information. The survey provided more information on both variables, but this data was excluded from Phase I to reduce the number of explanatory variables in the exploratory phase.

In order to address the possibility of correlated error terms between adoption decisions, the third phase estimated a multivariate probit model. Only variables found significant at the 25% level or greater from Phase I or II were included in these regressions. Reducing the explanatory variables in the multivariate analysis is a method used to assist convergence and provide more efficient estimates (Hendry, 1995). The multivariate analysis included three models, testing whether the errors among BMPs within the same category (nutrition, drylot and land management) were correlated. Final policy recommendations were based on the most robust model specification in terms of variable significance and overall regression significance. Figure 4.3 describes the process of selecting a final model specification. The following sections describe the results from each phase and justify final specification selection.

Figure 4.3 Empirical Steps to Develop Final Model Specification



4.2.1 Phase I: Estimation of Univariate Logit Model

The logit models were comprised of thirteen separate equations that corresponded to the thirteen best management practices listed in Figure 3.1. All of the explanatory variables listed in Table 3.2 were included in the Phase I regression. These BMP models were estimated using the NLOGIT 4.0 software program according to Equation 4.1.

(4.1) $BMP_i = f$ (SIZE, CROP, STATE, INVEST, REVENUE, EDUC, OWN, DIVERSE, EXPER, FUTURE, AGE, PROFIT, TECH, COST, AIR, WATER) + e

Where $BMP_i = 1$ if the feedlot operator adopted the *i*th BMP and 0 otherwise; e= error term

The results of the single equation logit analysis for each BMP are shown in Tables 4.6-4.14, include estimated coefficients and their respective standard errors and probability values. The likelihood ratio (LR) statistic, LR probability value, contingency tables and the McFadden R^2 for each model are measures of overall model goodness-of-fit. The contingency tables, in particular evaluate the models predictive success, for both the ‘yes’ and the ‘no’ decisions. The LR statistic and contingency tables are generally considered more appropriate than the R^2 statistic for qualitative choice models, but the McFadden R^2 is also provided. Table 4.5 provides a general overview of significance of the independent variables as well as signs of variables significant at the 25% level or greater across all practices.[2] If a variable does not display an asterisk, it was not significant greater than the 10% level.

The models testing the practices of adjusting crude protein (PROTEIN), practicing group feeding (GROUP) and applying an acidifier (ACID) failed to converge as a result of non-probabilistic prediction by the profit perception variable. Appendix B presents the results of PROTEIN and GROUP excluding the profit variable. No alternative model was estimated for applying an acidifier since so few operators adopt the practice. However, these practices ranked first, third and fourth in terms of percentage

[2] Significance up to 25% is shown in order to display variables that will be included in the multivariate analysis. Standard statistical interpretation holds, and variables are only considered to have a statistical impact if significant at least at the 10% level for all analyses.

adoption/non-adoption, so discrete choice analysis provides less explanatory power compared with practices that were characterized by a more varied decision across the sample set.

All of the explanatory variables with the exception of WATER, AGE and EDUC were significant at least at the 10% level in one or more models. SIZE and PROFIT were both significant in five of the ten models. DIVERSE, OWN, FUTURE, EXPER and TECH were each significant in two models. REVENUE, INVEST, COST, AIR and STATE were only found to be significant in one model.

Equation 4.1 was also estimated using a linear probability model (LPM). LPMs can be useful for preliminary models, or to assist convergence. Appendix D presents LPM results for thirteen models, but due to the shortcomings described in Chapter Three, LPMs will not be considered as a final model specification. Furthermore, in order to explore the possibility of endogeneity between perception variables and adoption, equations were estimated excluding PROFIT, TECH and COST. All variables remained significant with the exception of EXPER and OWN for the SOIL model. Overall model significance as indicated by the probability of the Likelihood Ratio statistic LR decreased for all models. Appendix C presents the coefficient estimates resulting from this specification.

Table 4.5 Signs and Significance of Explanatory Variables from Estimate of Univariate Logit Model

Indep./ Dep. Variable	NUTRITION	BEDDING	CLEAN	SURFACE	ADD	INCORP.	SOIL	RUNOFF	TEST	SHADE
SIZE	+ **		- **			+ ~	+ ~	+ **	+ ***	- **
CROP					- *		+ ~			- ~
REVENUE	- *		+ ~					- ~	- ~	+ ~
INVEST				+ ~				+ ~	+ ~	- **
DIVERSE	- ~					+ **	+ ~	- ~	- ~	- **
EXPER					- ~	+ *			+ **	+ ~
OWN			- ~		+ **	- **		- ~		+ ~
FUTURE		- ***			- *				- ~	
PROFIT	+ ***	+ ***				+ ***	+ ***		+ ***	- ~
COST	- **									
TECH							- ***	- ~	- ***	
AIR	- ~			+ ~						+ **
WATER	+ ~									
STATE				- *	+ ~	- ~				
AGE									- ~	
EDUC			+ ~						+ ~	+ ~

+/- positive/negative statistical relationship between dependent and independent variable; *significant at 1% level; **significant at 5% level, ***significant at 10% level; ~significant at 25% level

All models were found to be overall significant at least the 5% level, with the exception of ADD and SURFACE. ADD was significant at the 10% level, SURFACE was not significant. Particularly, SIZE and PROFIT were found to be positive and significant in half of the models.

4.2.1 Phase II: Refined Analysis

Phase II applies univariate logit regression, but redefines the STATE and FUTURE variables to improve explanatory power. A better understanding of the role of the state location in BMP adoption decisions would help policy and outreach efforts to target the appropriate state. FUTURE and STATE were revealed to be significant at the 25% level in three and four of the models, respectively, warranting further exploration.

Three dummies were created: IOWA, KANSAS and NEBRASKA where Colorado was used as the base case. Phase II results found STATE significant for the following models: SURFACE, CLEAN and INCORPORATE.

The implications of the FUTURE variable were less straightforward, but if retirement played a large role in adoption, outreach efforts may need to adapt strategies to a new generation of feedlot managers. If the variable FUTURE was significant at the 25% level, the Phase II model included all of the following variables: plans to retire in the near term versus later (RETIRE5, RETIRE15), plans to increase livestock in the near term versus later (LIVE5, LIVE15), plans to invest in buildings in the near term versus later (BUILD5, BUILD15) and plans to invest in land in the near term versus later (LAND5, LAND15), where a variable ending in “5” indicates plans for the next five years and a variable ending in “15” indicates plans for the next five to fifteen years. The significance of the FUTURE variable warranted further analysis for the following practices: BED, ADD and TEST further testing found one or more dummy variable significant for BED only.

4.2.3 Results from Phase I and Phase II

The following section describes results from the univariate logit procedure. Individual BMP regressions are discussed, with emphasis on the sign and statistical significance of explanatory variables. For example, if Phase II testing of STATE or FUTURE improved the model, these results were reported in lieu of Phase I results and the Phase I results are reported in Appendix B.

Hiring a Nutritionist

For NUTRITION (Table 4.6), the variables PROFIT and SIZE were positive and significant at the 1% and 5% level, respectively, while COST and REVENUE were negative and significant at the 5% and 10% level, respectively.

Using Feed Additives

The model for using a feed additive (ADD) found the variables CROP and FUTURE to be negative and significant at the 10% level (Table 4.7). The variable OWN was found to be positive and significant at the 5% level. Further exploration of the STATE variable, significant at the 25% level, did not reveal any link between specific state and adoption of ADD. Further testing of the FUTURE variable was inconclusive.

Providing Bedding in Drylot Pens

For BED, the variable PROFIT was positive and significant at the 1% level, and the variable FUTURE was negative and significant at the 1% level. The impact of the FUTURE variable was surprising, indicating that operators with some level of investment in the future (indicated investing in land, buildings or NOT retiring) were less likely to adopt this practice. When further tested using data on operator plans for next zero to five and five to fifteen years, the variables RETIRE5 and LIVE15 positively and negatively impacted BED adoption at the 5% level. Results for Phase II testing are presented in Table 4.8.

Removing Manure more than Four Times per Year

For CLEAN, further testing controlling for the exact state found that location in Iowa increases the likelihood of adoption, significant at the 10% level. OWN was found negative and significant at the 10% level. Phase II results are presented in Table 4.9, Phase I testing of CLEAN is presented in the Appendix B.

Collecting Runoff Water from Buildings and Pens

In the model for RUNOFF, the variable SIZE was the only significant explanatory variable; which was found to positively influence adoption (Table 4.10).

Providing Shade in Drylot Pens

For the practice of providing shade in drylot pens (SHADE) the variables SIZE, INVEST and DIVERSE were negative and significant, all at the 5% level (Table 4.11). AIR was found positive and significant at the 10% level. Further exploration of the

FUTURE variable, which was significant at the 25% level failed to reveal a link between the future variables and adoption of SHADE.

Applying Water to the Surface of Drylot Pens

The model for applying water to the surface of drylot pens (SURFACE) was not overall significant, and had only one significant explanatory variable. Phase II testing controlled for location in Iowa, Kansas or Nebraska, with Colorado being the base group. Including these variables improved the model and the variables controlling for location in Kansas and Iowa were found to be negative and significant at the 5% and 10% level, respectively. The results for Phase II testing are presented in Table 4.12, and the results of Phase I testing are presented in Appendix B.

Incorporate Manure within 48 Hours of Application

The INCORPORATE model found the variables DIVERSE, OWN, EXPER and PROFIT significant (Table 4.13). The variable PROFIT had the expected positive sign, and was significant at the 1% level. The variable DIVERSE was positive and significant at the 5% level, and EXPER was positive and significant at the 10% level. The variable OWN was negative and significant at 5%, strongly implying that operations that own a large percentage of their cropland were less likely to adopt this practice. The variable STATE was found significant at the 25% level, and further testing controlling for each state found that location in Nebraska and Iowa negative and significant at the 1% and 10% level, respectively. EXPER was no longer significant. In order to determine whether there was a threshold level of ownership where this relationship held true, models including dummies for owning 50% or more, 75% or more and 90% or more were separately estimated. Results were unchanged, OWN remained negative and significant, and none of the dummy variables were found significant.

Testing Manure, Crop and Effluent for Nutrients

The TEST model found the variables PROFIT and SIZE significant at the 1% level, with expected positive signs (Table 4.14). EXPER was positive and significant at the 5% level and TECH was negative and significant at the 1% level.

Perform a Yearly Soil Test for Crop Nutrients

The SOIL model found the variables PROFIT and TECH significant at the 1% level with expected signs (Table 4.15). The model excluding the PROFIT variable from PROTEIN and GROUP found no variables significant for PROTEIN and only AGE significant for GROUP. Appendix B provides these results.

4.2.4 Multivariate Probit Analysis

If the error terms among equations have a correlated component, coefficient estimates could be biased, resulting in misleading policy conclusions. Following recommendations by soil and crop scientists, it was hypothesized that adoption decisions among similar categories (feeding, drylot and land management) of BMPs could be correlated. As such, the BMPs were divided into three multivariate probit regressions. The models were estimated using NLOGIT 4.0 according to Equation 3.12.

Variables found significant at the 25% level or greater in either phase were included in the multivariate analysis. If one of the variables comprising FUTURE or STATE was found significant, FUTURE or STATE was replaced by the more specific variable(s). For example, if IOWA and KANSAS were found significant in Phase II, the multivariate equation excluded STATE in favor of IOWA and KANSAS. Tables 4.16 - 4.18 present the parameter estimates, standard errors, p-values as well as the correlation coefficients, and their respective standard errors and p-values. Only the BMPs INCORPORATE and TEST were found to be correlated, significant at the 5% level. As both of these practices are water quality BMPs, often implemented as part of a Nutrient Management Plan, this result was not surprising. OWN was no longer found to explain the decision to adopt INCORPORATE, though SIZE did. EXPER was no longer significant for the TEST model.

4.2.5 Marginal Probabilities

Marginal probabilities for each variable were calculated using the equations presented in Chapter 3.10 using coefficients from Phase I modeling and means of each variable. The means were unique to each practice, since only responses that answered "yes," or "no" were included in each single equation logit model. The variable means used to calculate the marginal probability are presented in Appendix C. Table 4.19 presents the marginal probabilities of each variable for each BMP modeled.

4.2.6 Probability of Adoption

The probability that the average operator adopted each BMP was calculated using Equations 3.5 and 3.6 using the coefficients estimated in the Phase I univariate analysis (Table 4.20). For this calculation, dummy variables were left at the average, rather than rounded.

Table 4.20 Predicted Probability of Adoption Using Logit Coefficients

BMP	Predicted Probability of Adoption	Actual Percent Adopted
NUTRITION	0.99	77%
ADD	0.99	96%
SOIL	0.97	78%
TEST	0.79	59%
RUNOFF	0.76	67%
CLEAN	0.71	60%
BED	0.64	52%
INCORP	0.43	42%
SURFACE	0.28	28%
SHADE	0.27	34%

The predicted probabilities of adoption were found to be qualitatively similar to the actual percent adopting from the sample. These probabilities provide a starting point for policy and outreach strategy, though particularly interesting is how the probability of adoption varies if certain targetable attributes are varied- which can be found in the concluding section. These results will be placed in context with adoption rates and overall statistical findings in order to provide adoption scenarios by operator categories.

4.3 Summary of Results

This chapter presented the empirical results of the univariate analysis which included all explanatory variables (Phase I), as well as the results from further exploring the STATE and FUTURE variable (Phase II). The results from the univariate analysis revealed that each practice was influenced by a unique set of variables. The multivariate analysis provided little additional explanatory power. Regardless, the number of cattle (SIZE) and operator perception of profitability of the practice (PROFIT) had the most consistent impact on adoption, increasing adoption rates for five of the ten BMPs. Other economic perception variables (COST and TECH) had the expected negative sign, but only significantly influence adoption for three practices. The concluding chapter will summarize each practice, synthesizing information on adoption rates, econometric results and sensitivity of probability of adoption to changes in attributes.

Table 4.6 Phase I Univariate Logit Results for Dependent Variable NUTRITION

NUTRITION n=150	Coefficient	St. error	P-value
CONSTANT**	-4.4458	1.8519	0.0164
PROFIT***	1.1170	0.2950	0.0002
TECH	0.0036	0.0132	0.7843
SIZE**	0.0014	0.0006	0.0277
CROP	0.0002	0.0003	0.2585
COST**	-0.7843	0.3395	0.0209
INVEST	0.0000	0.0000	0.4291
FUTURE	-0.1936	0.8141	0.8120
DIVERSE	-0.0016	0.0013	0.2024
REVENUE*	-0.0013	0.0007	0.0871
OWN	-0.0024	0.0025	0.3432
EXPER	0.0001	0.0014	0.9297
STATE	1.7004	1.5053	0.2587
EDUC	0.0016	0.0018	0.3707
AGE	-0.0007	0.0011	0.5096
WATER	1.4888	1.0025	0.1375
AIR	-1.4879	1.0027	0.1378
Likelihood Ratio(LR)	89.8530		
LR P-value	.0000		
McFadden R^2	0.55		

	% Predicted	
% Actual	0	1
0	74%	26%
1	4%	96%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.7 Phase I Univariate Logit Results for Dependent Variable ADD

ADD n=147	Coefficient	St. error	P-value
CONSTANT**	6.8839	3.3167	0.0379
PROFIT	0.0018	0.0269	0.9479
TECH	-0.0155	0.0314	0.6225
SIZE	0.0009	0.0009	0.2698
CROP*	-0.0004	0.0002	0.0834
COST	-0.5988	0.6413	0.3504
INVEST	0.0000	0.0000	0.2843
FUTURE*	-3.0012	1.6968	0.0769
DIVERSE	0.0020	0.0026	0.4271
REVENUE	0.0002	0.0012	0.8817
OWN**	0.0043	0.0022	0.0477
EXPER	-0.0692	0.0500	0.1667
STATE	2.6413	1.9754	0.1812
EDUC	0.0087	0.0080	0.2763
AGE	-0.0048	0.0073	0.5091
WATER	-0.0023	0.0050	0.6429
AIR	0.0031	0.0051	0.5451
Likelihood Ratio(LR)	24.8992		
LR P-value	.0716		
McFadden R^2	0.44		

	% Predicted	
% Actual	0	1
0	78%	22%
1	14%	86%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.8 Phase II Univariate Logit Results for Dependent Variable BED

BED n=146	Coefficient	St. error	P-value
Constant***	-4.9018	1.2921	0.0001
PROFIT***	1.6956	0.3012	0.0000
TECH	7.36E-04	0.0102	0.9424
SIZE	-2.58E-05	1.67E-05	0.1237
COST	8.46E-04	2.29E-03	0.7112
INVEST	-3.42E-06	3.26E-06	0.2933
BUILD5	7.76E-04	7.47E-04	0.2988
BUILD15	-2.48E-04	6.58E-04	0.7062
LIVE5	1.13E-03	6.87E-04	0.1001
LIVE15**	-1.44E-03	7.17E-04	0.0453
RETIRE5**	1.42E-03	6.69E-04	0.0337
RETIRE15	6.87E-05	6.26E-04	0.9125
DIVERSE	-1.56E-03	9.72E-04	0.1073
REVENUE*	1.09E-03	5.69E-04	0.0558
OWN	9.42E-04	9.20E-04	0.3060
EXPER	-1.60E-03	1.48E-03	0.2812
STATE	0.9903	0.8596	0.2493
AGE	1.30E-03	8.57E-04	0.1300
Likelihood Ratio(LR)	99.1827		
LR P-value	.0000		
McFadden R^2	0.49		

	% Predicted	
% Actual	0	1
0	79%	21%
1	15%	85%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.9 Phase II Univariate Logit Results for Dependent Variable CLEAN

CLEAN n=153	Coefficient	St. error	P-value
CONSTANT	0.9794	0.7041	0.1642
PROFIT	-2.74E-03	5.60E-03	0.6250
TECH	3.17E-03	5.35E-03	0.5537
SIZE	1.81E-03	1.45E-03	0.2131
COST	-1.06E-05	1.58E-05	0.5044
INVEST	1.45E-06	2.54E-06	0.5692
FUTURE	-0.6342	0.5354	0.2362
DIVERSE	5.13E-05	6.92E-04	0.9409
REVENUE	6.98E-04	4.50E-04	0.1205
OWN*	-2.06E-03	1.16E-03	0.0755
EXPER	8.95E-04	9.72E-04	0.3573
IOWA*	1.3847	0.7093	0.0509
KANSAS	-0.8565	0.7388	0.2463
NEBRASKA	-0.3188	0.7140	0.6553
EDUC	1.82E-03	1.30E-03	0.1628
AGE	-3.58E-04	1.14E-03	0.7532
WATER	-1.85E-03	1.44E-03	0.2007
AIR	3.26E-04	8.31E-04	0.6948
Likelihood Ratio (LR)	47.7290		
LR P-value	.0250		
McFadden R^2	0.14		

	% Predicted	
% Actual	0	1
0	81%	19%
1	18%	82%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.10 Phase I Univariate Logit Results for Dependent Variable RUNOFF

RUNOFF n=152	Coefficient	St. error	P-value
CONSTANT	0.3024	1.0395	0.7711
PROFIT	0.0827	0.1400	0.5546
TECH	-0.2374	0.1906	0.2128
SIZE**	0.0001	0.0001	0.0314
CROP	0.0000	0.0001	0.8166
COST	0.1546	0.1978	0.4344
INVEST	5.31E-06	4.04E-06	0.1893
FUTURE	-0.0563	0.5061	0.9115
DIVERSE	-0.0017	0.0011	0.1290
REVENUE	-0.0007	0.0004	0.1338
OWN	-0.0016	0.0011	0.1486
EXPER	0.0013	0.0013	0.3439
STATE	-0.4640	0.9355	0.6199
EDUC	0.0012	0.0014	0.3864
AGE	-0.0005	0.0009	0.6175
WATER	0.0017	0.0017	0.3035
AIR	-0.0005	0.0013	0.6965
Likelihood Ratio(LR)	36.8989		
LR P-value	.0022		
McFadden R2	0.19		

	% Predicted	
% Actual	0	1
0	45%	55%
1	13%	87%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.11 Phase I Univariate Logit Results for Dependent Variable SHADE

SHADE n=148	Coefficient	St. error	P-value
CONSTANT	-0.1659	1.3124	0.8994
PROFIT	-0.0051	0.0033	0.1211
TECH	0.0011	0.0026	0.6823
SIZE**	-0.0001	3.49E-05	0.0174
CROP	-0.0002	0.0001	0.1691
COST	0.0028	0.0034	0.4107
INVEST**	0.0000	0.0000	0.0107
FUTURE	-1.62E-05	0.5494	0.2715
DIVERSE**	-0.0031	0.0012	0.0109
REVENUE	0.0007	0.0005	0.1230
OWN	0.0016	0.0010	0.1030
EXPER	0.0016	0.0014	0.2442
STATE	0.9295	1.2062	0.4410
EDUC	0.0029	0.0025	0.2351
AGE	0.0001	0.0011	0.9531
WATER	-	-	-
AIR**	2.65E-03	1.29E-03	0.0394
Likelihood Ratio (LR)	52.8291		
LR P-value	.0000		
McFadden R^2	0.27		

	% Predicted	
% Actual	0	1
0	86%	14%
1	38%	62%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.12 Phase II Univariate Logit Results for Dependent Variable SURFACE

SURFACE n=148	Coefficient	St. error	P-value
CONSTANT	4.90E-02	0.6600	0.9412
PROFIT	1.23E-03	1.42E-03	0.3885
TECH	9.16E-04	1.53E-03	0.5506
SIZE	-1.22E-06	1.57E-05	0.9382
COST	-1.02E-03	1.72E-03	0.5518
INVEST	3.37E-06	2.29E-06	0.1417
FUTURE	-3.95E-02	0.5241	0.9401
DIVERSE	-6.20E-04	6.98E-04	0.3749
REVENUE	-1.81E-04	4.18E-04	0.6654
OWN	-7.89E-04	6.97E-04	0.2578
EXPER	2.37E-04	9.54E-04	0.8040
IOWA*	-1.2635	0.6706	0.0596
KANSAS**	-2.0499	0.7971	0.0101
NEBRASKA	-0.6555	0.6894	0.3417
EDUC	-2.57E-04	1.21E-03	0.8313
AGE	-1.28E-04	9.60E-04	0.8939
WATER	-1.29E-03	1.30E-03	0.3190
AIR	2.03E-03	1.56E-03	0.1929
Likelihood Ratio (LR)	16.9039		
LR P-value	.6971		
McFadden R^2	0.09		

	% Predicted	
% Actual	0	1
0	95%	5%
1	67%	33%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.13 Phase II Univariate Logit Results for Dependent Variable INCORPORATE

INCORPORATE n= 148	Coefficient	St. error	P-value
CONSTANT*	-2.9141	-1.8210	0.0687
PROFIT***	1.3597	5.1800	0.0000
TECH	2.94E-03	0.2380	0.8115
SIZE	1.72E-05	0.5910	0.5548
COST	8.67E-04	0.5440	0.5862
INVEST	3.03E-06	0.9940	0.3202
FUTURE	0.5488	0.8040	0.4212
DIVERSE*	2.42E-03	1.7200	0.0854
REVENUE	-5.72E-04	-1.0560	0.2909
OWN**	-1.83E-03	-1.9750	0.0483
EXPER	3.17E-03	1.4780	0.1395
IOWA*	-1.9640	-1.8640	0.0624
KANSAS	-0.8309	-0.7540	0.4511
NEBRASKA***	-3.0255	-2.7000	0.0069
EDUC	2.02E-02	0.8730	0.3828
AGE	-2.07E-02	-0.9350	0.3500
WATER	0.5890	0.7130	0.4756
AIR	-0.5891	-0.7130	0.4756
Likelihood Ratio(LR)	93.2200		
LR P-value	.0000		
McFadden R^2	0.45		

	% Predicted	
% Actual	0	1
0	84%	16%
1	21%	79%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.14 Phase I Univariate Logit Results for Dependent Variable TEST

TEST n=150	Coefficient	St. error	P-value
CONSTANT	-1.1006	1.0294	0.2850
PROFIT***	1.0456	0.3113	0.0008
TECH***	-1.0493	0.3113	0.0007
SIZE**	0.0002	0.0001	0.0039
CROP	0.0000	0.0001	0.8658
COST	0.0058	0.0075	0.4380
INVEST	5.92E-06	4.08E-06	0.1472
FUTURE	-0.7211	0.5679	0.2041
DIVERSE	-0.0014	0.0011	0.1777
REVENUE	-0.0007	0.0005	0.1581
OWN	-0.0009	0.0009	0.3058
EXPER**	0.0051	0.0020	0.0133
STATE	0.8728	0.9179	0.3417
EDUC	0.0020	0.0017	0.2410
AGE	-0.0019	0.0012	0.1094
WATER	0.0007	0.0018	0.6821
AIR	-0.0012	0.0017	0.4823
Likelihood Ratio (LR)	72.4570		
LR P-value	.0000		
McFadden R^2	0.36		

	% Predicted	
% Actual	0	1
0	74%	26%
1	13%	87%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.15 Phase I Univariate Logit Results for Dependent Variable SOIL

SOIL n=150	Coefficient	St. error	P-value
CONSTANT	1.1814	1.1547	0.3062
PROFIT***	0.8612	0.2667	0.0012
TECH***	-0.8609	0.2666	0.0012
SIZE	0.0001	0.0001	0.1285
CROP	0.0002	0.0001	0.1991
COST	0.0009	0.0018	0.6347
INVEST	2.80E-06	4.05E-06	0.4883
FUTURE	-0.0219	0.5908	0.9705
DIVERSE	-0.0015	0.0013	0.2478
REVENUE	-0.0001	0.0005	0.8267
OWN	0.0002	0.0008	0.8401
EXPER	0.0014	0.0011	0.2021
STATE	-0.2562	1.0122	0.8002
EDUC	0.0001	0.0016	0.9398
AGE	0.0002	0.0011	0.8470
WATER	0.0004	0.0016	0.8123
AIR	-0.0005	0.0016	0.7428
Likelihood Ratio (LR)	28.5857		
LR P-value	.0269		
McFadden R^2	0.18		

	% Predicted	
% Actual	0	1
0	15%	85%
1	4%	96%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.16 Bivariate Probit Results for Feeding Ammonia BMPs (NUTRITON, ADD)

Variable	Coefficient	St. Error	P-value
		NUTRITION	
Constant	-1.1792	0.7229	0.1028
SIZE***	0.0008	0.0002	0.0004
PROFIT***	0.5033	0.1375	0.0003
COST*	-0.2819	0.1594	0.077
REVENUE	-0.0003	0.0004	0.3943
AIR	-0.509	0.3633	0.1612
WATER	0.5093	0.3633	0.1609
		ADD	
Constant	1.6995	1.4406	0.2381
SIZE	0.0003	0.0007	0.7157
CROP*	-0.0001	0.0001	0.0921
PROFIT	-0.0016	0.0804	0.9838
EXPER	-0.0118	0.0343	0.7313
OWN	0.0014	0.0015	0.3421
FUTURE	-0.9359	0.9132	0.3055
REVENUE	0.0002	0.0007	0.8216
STATE	0.7564	1.26	0.5483
Correlation coefficients			
R(01,02)	-0.6060	1.1576	0.6006

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.17 Multivariate Probit Results for Drylot Ammonia BMPs (BED, CLEAN, RUNOFF, SHADE)

Variable	Coefficient	St. Error	P-value
		BED	
Constant***	-2.3091	0.4245	1E-07
SIZE*	-1.55E-05	8.46E-06	0.0676
RETIRE5**	0.0009	0.0004	0.0209
LIVE15**	-0.0007	0.0003	0.0326
LIVE5**	0.0007	0.0004	0.0396
PROFIT***	0.8464	0.1427	2.9E-07
DIVERSE	-0.0006	0.0006	0.3365
		CLEAN	
Constant*	0.5893	0.3339	0.0776
SIZE	1.53E-05	2.62E-05	0.5582
PROFIT	0.0011	0.001	0.2732
INVEST	9.07E+03	1.24E-06	0.4641
REVENUE**	0.0006	0.0003	0.0369
EDUC	0.0011	0.0007	0.1258
IOWA***	0.9296	0.2763	0.0008
KANSAS***	-0.9317	0.2698	0.0006
OWN	-0.001	0.0012	0.3947
		RUNOFF	
Constant	-0.4467	0.2766	0.1063
SIZE***	0.0006	0.0002	0.0033
PROFIT	0.1209	0.1052	0.2502
TECH	-0.121	0.1052	0.2501
INVEST	1.74E-06	4.50E-06	0.6985
REVENUE	-0.0003	0.0003	0.3457
DIVERSE	-0.0008	0.0008	0.2853
OWN	-0.0009	0.0008	0.2194
		SHADE	
Constant	0.3407	0.2679	0.2036
SIZE***	-0.0001	1.62E-05	0.0013
PROFIT	-0.0023	0.0045	0.6066
COST	0.0019	0.0045	0.6774
CROP	-0.0001	0.0001	0.2845
INVEST	7.53E-06	4.93E-06	0.1262
EXPER	0.001	0.002	0.6201
REVENUE*	0.0005	0.0003	0.0762
DIVERSE***	-0.002	0.0005	0.0001
OWN	0.0015	0.0015	0.3385

Table 4.17 Continued

Correlation coefficients			
R(01,02)	0.2128	0.3102	0.4927
R(01,03)	0.3430	0.2520	0.1735
R(02,03)	-0.3143	0.2091	0.1514
R(01,04)	0.2434	0.2006	0.2249
R(02,04)	-0.1551	0.2423	0.5220
R(03,04)	0.0069	0.2379	0.9767

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.18 Multivariate Probit Results for Land Ammonia BMPs (SOIL, TEST, INCORPORATE)

Variable	Coefficient	St. Error	P-value
		SOIL	
Constant***	1.3589	0.3141	0.0001
SIZE	-1.55E-05	0.0001	0.6662
PROFIT***	0.4021	0.1416	0.0045
TECH***	-0.4018	0.1415	0.0045
KANSAS	-0.7727	0.5096	0.1295
IOWA**	-0.8273	0.3389	0.0146
		TEST	
Constant	0.1503	0.1569	0.3381
SIZE***	0.0001	1.94E-04	0.0042
PROFIT***	0.5969	0.1864	0.0014
TECH***	-0.5959	0.1864	0.0014
EXPER	0.0018	0.0014	0.2092
		INCORPORATE	
Constant***	-2.7292	0.5326	0.0001
SIZE**	-5.21E-05	1.62E-05	0.0458
PROFIT***	0.7347	0.1502	0.0001
OWN	-0.0009	0.0006	0.1288
DIVERSE***	0.0013	0.0004	0.0021
Correlation coefficients			
R(01,02)	0.3026	0.2093	0.1483
R(01,03)	0.0285	0.2106	0.8922
R(02,03)**	0.3777	0.1826	0.0387

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table 4.19 Marginal Probabilities by BMP for Phase I Univariate Logit Analysis

	NUTRITION	BEDDING	CLEAN	SURFACE	ADD	INCORP	SOIL	RUNOFF	TEST	SHADE
PROFIT	7.26E-05	0.000105	2.46E-08	6.59E-08	1.14E-07	8.32E-05	5.60E-05	5.38E-06	6.80E-05	-3.30E-07
TECH	2.34E-07	3.32E-08	8.50E-08	7.05E-08	-1.00E-06	1.84E-07	-5.60E-05	-1.50E-05	-6.80E-05	7.05E-08
COST	-5.10E-05	3.04E-08	4.77E-08	-6.90E-08	-3.90E-05	5.86E-08	5.70E-08	1.01E-05	3.78E-07	1.83E-07
AIR	-9.67E-05	-5.70E-08	-2.40E-08	1.62E-07	2.02E-07	-4.30E-05	-3.50E-08	-3.40E-08	-8.00E-08	1.72E-07
WATER	9.68E-05	1.17E-07	-9.30E-08	-9.50E-08	-1.50E-07	4.28E-05	2.52E-08	1.11E-07	4.82E-08	-
SIZE	9.25E-08	-9.40E-10	-2.10E-09	-5.50E-10	6.14E-08	2.14E-09	5.17E-09	9.08E-09	1.59E-08	-5.40E-09
CROP	1.60E-08	5.80E-10	-3.50E-09	2.23E-09	-2.60E-08	2.58E-09	1.14E-08	1.53E-09	-1.10E-09	-9.90E-09
OWN	-1.55E-07	2.35E-08	-1.10E-07	-5.00E-08	2.80E-07	-1.30E-07	1.08E-08	-1.00E-07	-5.70E-08	1.05E-07
STATE	0.00001	5.31E-05	5.11E-05	-7.40E-05	0.000172	-7.10E-05	-1.70E-05	-3.00E-05	5.68E-05	6.05E-05
EXPER	7.97E-09	-8.00E-08	4.37E-08	1.09E-08	-4.50E-06	2.02E-07	8.80E-08	8.17E-08	3.29E-07	1.06E-07
AGE	-4.50E-08	3.84E-08	-3.80E-08	-2.60E-08	-3.10E-07	-6.60E-07	1.32E-08	-3.00E-08	-1.30E-07	4.22E-09
INVEST	3.53E-10	-7.60E-12	5.15E-11	1.99E-10	-3.50E-10	1.67E-10	1.82E-10	3.45E-10	3.85E-10	-1.1E-09
FUTURE	-1.25E-05	-0.00012	-3.10E-05	5.17E-06	-0.0002	1.99E-05	-1.40E-06	-3.70E-06	-4.70E-05	3.93E-05
EDUC	1.06E-07	6.17E-08	1.05E-07	-1.10E-08	5.66E-07	5.98E-07	8.09E-09	7.93E-08	1.28E-07	1.92E-07
REVENUE	-8.18E-08	2.69E-08	3.24E-08	2.63E-08	1.42E-07	6.30E-08	1.31E-05	3.29E-07	3.29E-07	3.29E-07
DIVERSE	-1.05E-07	-6.9E-08	-3.50E-09	-3.40E-08	1.33E-07	1.59E-07	-9.80E-08	-1.10E-07	-9.40E-08	-2.00E-07

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND FUTURE DIRECTION

Ammonia emissions from feedlots and dairies have become an increasing public concern. Fine particulate matter formed from ammonia emissions not only impacts human health but has been linked to altering the fragile ecosystem of Rocky Mountain National Park. Ammonia emissions from animal agriculture remain unregulated, and Colorado has chosen to adopt a best management practice approach, whereby operators choose the site-specific practice(s) that best suit their operation. As such, managers of animal agriculture operations play a key role in mitigating future environmental damage by adopting certain practices that reduce the potential for ammonia to convert to gas.

Since this issue has only relatively recently moved to the forefront of environmental policy, little information existed documenting current adoption rates of BMPs aimed at reducing ammonia emissions. This particular study looked at adoption rates as well as results from discrete choice analysis to identify possible incentives and barriers to adoption- an effort supported by the National Resource Conservation Service to encourage voluntary BMP adoption. The data used for this analysis was collected from a survey, distributed to feedlot operators in four states.

The first objective of this research was addressed by analyzing survey data. In 2007, Colorado State University researchers designed a survey following the Dillman technique requesting information on farm characteristics, operator demographic information and adoption rates of thirteen BMPs. The survey was sent to operations in Colorado, Kansas, Nebraska and Iowa. Chapter Three outlined specific data requested from respondents, while Chapter Four presented summary statistics. The thirteen surveyed practices ranged from near universal adoption to very low adoption.

The second objective employed discrete choice modeling to examine the influence of explanatory variables on the probability of adoption of the surveyed BMPs. Hypothesized variables included operation characteristics: size of operation, investment capabilities, ownership and diversity of operation, as well as operator characteristics: age, education and experience of the feedlot manager. Finally, perceptions of profitability, cost, and outside technical requirements as well as the impact on air and water quality were hypothesized to influence adoption. Chapter Three detailed the theory supporting the inclusion of each of these variables, derived from previous research as well as knowledge of the specific ammonia BMPs.

The discrete choice modeling involved three distinct phases: an initial single-equation logit analysis of each BMP, further exploration of unexpected signs and index variables, and a multivariate probit analysis of the most significant variables. Chapter Three outlined the methodology used to derive parameter estimates in both the univariate and multivariate case. Chapter Four presented the results from the discrete choice modeling. This chapter discusses the framework through which policy-makers and outreach professionals should evaluate these results from. Within this framework, the final section synthesizes information on adoption rates and the statistical findings to provide a profile of each BMP as well as possible policy and outreach directions.

5.1 Policy Recommendations

Using the empirical results presented in Chapter Four to guide an outreach policy depends on three factors. First, the overall performance of the statistical model determines whether policy recommendations can draw from statistical inference above and beyond summary statistics. Chapter Four showed that except for the SURFACE model, all of the models provided explanatory power that can be used to answer the initial research questions. Second, current adoption rates and overall ammonia reduction potential of each BMP determines how much “bang for the buck,” can be achieved via promotion. The current adoption rates were provided in Chapter Four, and animal and soil scientists remain most qualified to determine the mitigation potential of each BMP.

Third, sensitivity of the probability of adoption to changes in targetable attributes determines whether or not an outreach strategy will be effective if a given BMP is worthwhile. For example, a statistically significant model for a BMP with ammonia reduction potential that does not predict adoption over a realistic range of attributes, or over attributes than can be easily identified by outreach professionals, is of little use for policy purposes.

In order to address this issue, two exercises were conducted to determine *how* policy can feasibly impact adoption. Initially, values of policy-relevant variables were varied across the range of values found in this sample in order to determine how the probability of adoption varies for a given attribute, *ceteris perebis*. Specifically, different values of the SIZE, PROFIT and TECH variables were plotted against the probability of adoption, using Equation 3.7 (Figures 5.1-5.3). Only those practices which were found to have a statistically significant relationship with the variable of interest were mapped in these figures. SIZE was selected due to the fact that this is an easily identifiable characteristic. PROFIT and TECH were selected because they indicate BMP-specific constraints that can be reduced via cost-sharing programs or in-kind support. The slope of each function at any point indicates both the sign of the statistical relationship as well as the sensitivity of the probability to a change in that attribute.

Of practical interest is the variable value at which point the probability of adoption begins to asymptotically approach one. For example, Figure 5.1 shows that high probabilities of adoption (say, 0.90) are reached at much smaller operation sizes for the practice of hiring a nutritionist than for the practice of collecting runoff. This can either be interpreted as NUTRITION is a more viable practice for medium-sized operations *or* that RUNOFF provides potential for increased adoption among medium-sized operations.

Figures 5.2 and 5.3 provide information on the practices that would most benefit from technical assistance or a cost-share program. With the exception of SOIL and RUNOFF, the practices presented in these figures are highly responsive to the respective economic perception. Policies addressing these producer concerns could be an effective means to encourage voluntary adoption.

Figure 5.1 Probability of Adopting BMPs by Size of Operation

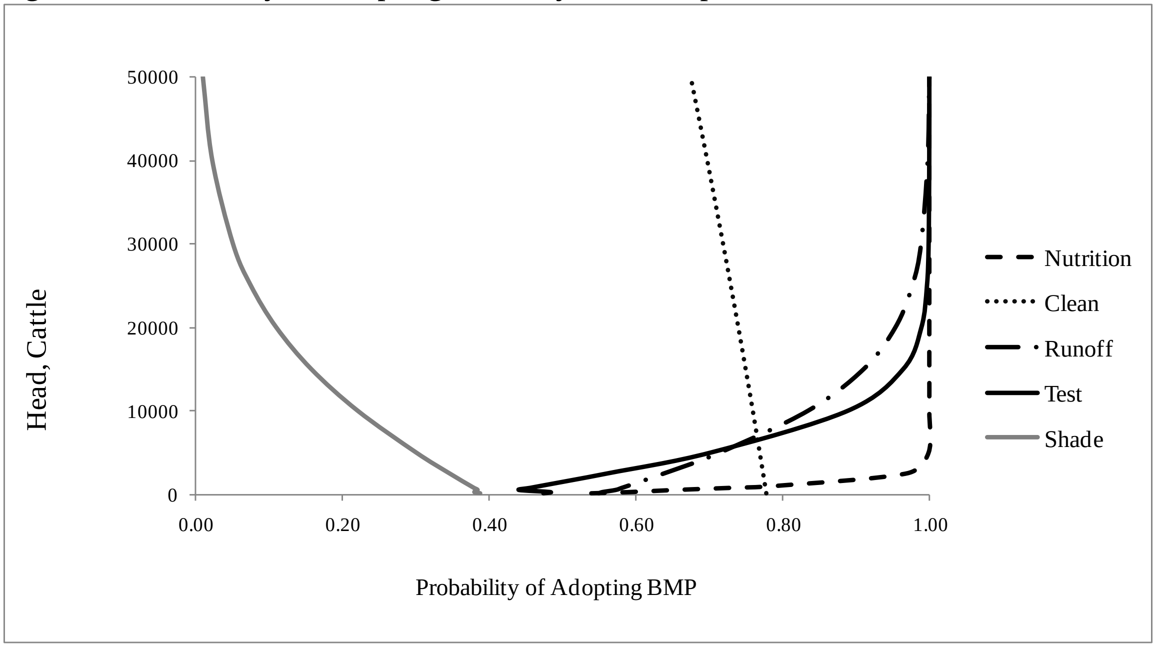


Figure 5.2 Probability of Adopting BMP by Perception of Profitability

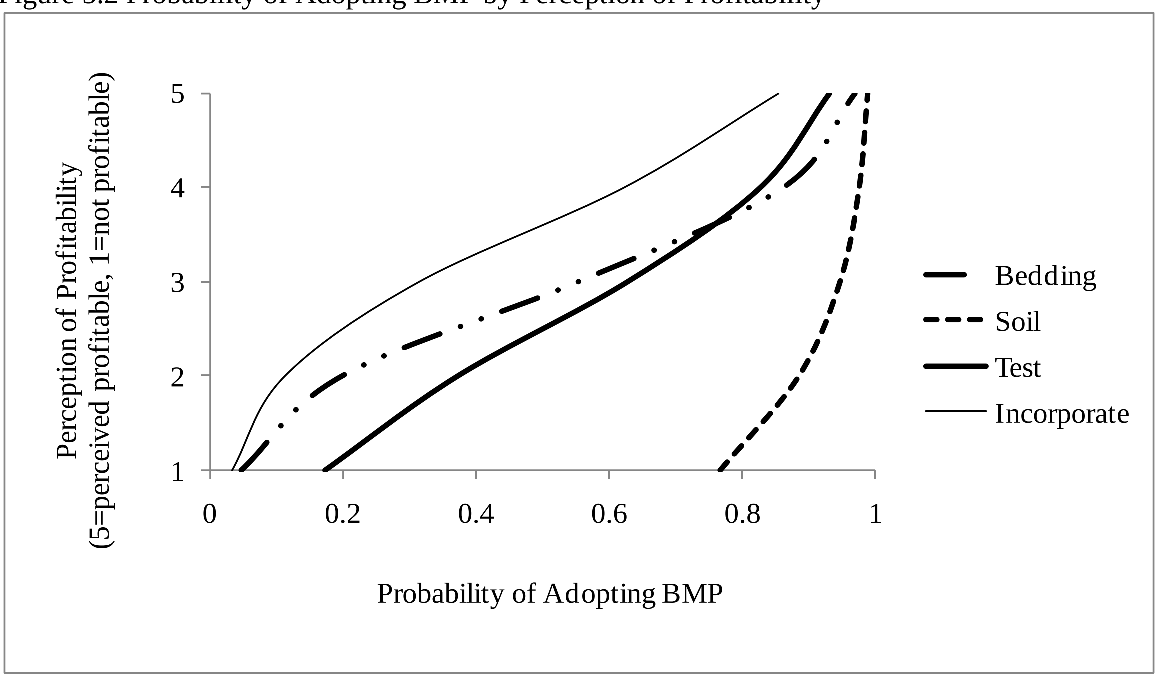
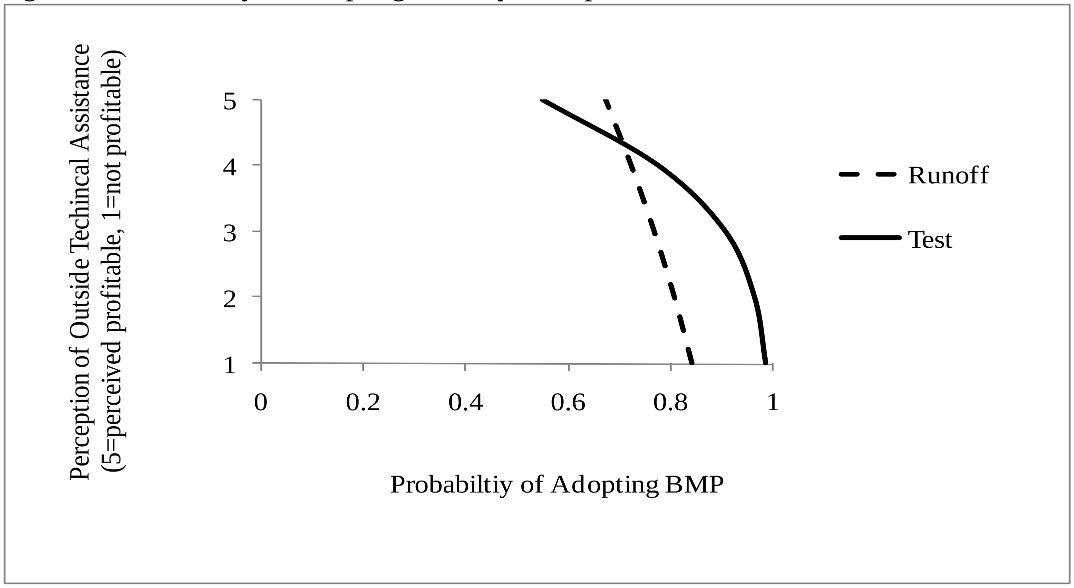


Figure 5.3 Probability of Adopting BMP by Perception of Outside Technical Assistance



Next, sets of attributes were varied in order to determine what attribute(s) could increase the probability of adoption high enough that outreach personnel can be fairly confident that a given practice will be adopted by an operator with that set of attributes. Table 5.1 lists attributes, or sets of attributes on the left-hand side, and BMPs along the top. Within the table, exact probabilities are not displayed, rather ranges, identified by levels of shading. Here, the exact numerical probability is of less interest than is the impact that releasing economic constraints has on increasing the probability of adoption among non-adopting groups (typically small producers).

For example, looking at Table 5.1, the model predicted adoption of NUTRITION for all sizes of operations. However, for the smallest operations in the sample (less than 500 animals), the model only marginally predicted adoption. If this practice were to provide worthwhile ammonia reductions, this model suggests that a policy that were to release the cost or profit barrier would enable at least 75% of operations of that size to adopt. Releasing the technology constraint on TECH would have the same effect.

In the case of the BED and INCORP models, SIZE was not found to statistically influence adoption; rather the profit perception variable was the only significant economic perception variable. Indeed, the probability of adopting BED heavily depended on the value of this variable. Adopting INCORP was only predicted if the operator explicitly agreed that this practice is profitable (Likert value of 4 or higher), the average adopter was not predicted to adopt. BED and TEST predicted adoption for the average producer, but increasing the profit variable increased the certainty of adoption. Further research should examine the actual on-farm profitability of adopting BED, INCORP and TEST and address constraints accordingly. ADD was not included because no attribute reduced probability of adoption to less than 0.90.

Smaller operations were more likely to adopt CLEAN and SHADE. Promoting SHADE to small practices only led to a probability of adoption beyond 0.60 if part of a low investment and non-diverse operator profile.

Table 5.1 Probability of Adoption, by Attribute

Attribute(s)	NUTR.	BEDDING	CLEAN	SURFACE	INCORP.	SOIL	RUNOFF	TEST	SHADE
Average Producer				x	x				x
Small	~	n/a		n/a	n/a	n/a	~	x	x
Large		n/a		n/a	n/a	n/a			x
Very Large		n/a			n/a	n/a			x
High Profit, Average			n/a	n/a			n/a		n/a
High Profit, Small		n/a	n/a	n/a	n/a	n/a	n/a		n/a
High Profit, Large		n/a	n/a	n/a	n/a	n/a	n/a		n/a
High Profit, Very Large		n/a	n/a	n/a	n/a	n/a	n/a		n/a
Low Profit, Average		x	n/a	n/a	x		n/a	x	n/a
Low Profit, Small	x	n/a	n/a	n/a	n/a	n/a	n/a	x	n/a
Low Cost, Small		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
High Tech, Average	n/a	n/a	n/a	n/a	n/a		n/a	~	n/a
Low Tech, Average	n/a	n/a	n/a	n/a	n/a		n/a		n/a
Low Tech, Small	n/a	n/a	n/a	n/a	n/a		n/a		n/a
Small, Low Invest	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	~
Small, Low Invest, Non-diverse	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Large, Experienced	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a

Low Profit/Tech/Cost= Likert value '1'; High Profit/Tech/Cost= Likert value '5'; Low Invest= $10,000 per year; Non-diverse=100% revenues generated from feedlot operation; Experienced= 55 years managing feedlot; Small= 500 head; Large=10,000 head; Very Large=30,000 head

	Probability of adoption greater than 0.90
	Probability of adoption between 0.75 and 0.89
	Probability of adoption between 0.60 and 0.74
~	Probability of adoption between 0.50 and 0.59
x	Probability of adoption less than 0.50
n/a	Variable not significant for specific practice

5.2 Synthesis

This section uses the above framework to isolate policy-relevant points for each of the BMPs, considering current adoption rate, statistical performance of the econometric models, variable significance, and impact of a given variable on overall adoption.

1. Hiring a nutritionist- The significance of SIZE indicated that operations with more animals were more likely to hire a nutritionist, likely motivated by the ability of larger operations to distribute the fixed cost of a nutritionist over a greater level of output. NUTRITION was perceived as more profitable and less costly than the average surveyed BMP, which likely explained the current 77% adoption rate. Probability of adoption remained above 0.75 regardless of changes in profit and cost perceptions, though probability of adoption was sensitive to size, as small operations were only marginally predicted to adopt. For operations with fewer than 500 animals, increasing the profit perception variable to five or decreasing the cost perception variable to one, increased the probability of adoption to above 0.80 in each case. Outreach and policy should focus on addressing cost barriers to small operations. Changing cost-efficiency (REVENUE) did not have a noticeable effect on the probability of adoption.

2. Using feed additives- This practice had the highest adoption level of any practice- near universal- so discrete choice modeling was less informative. Clearly, some factor motivates adoption, but since adoption levels are already so high, outreach efforts may be better spent promoting less commonly adopted practices. Indeed, varying attributes had a negligible effect on the high probability of adoption.

3. Yearly soil test- SOIL was perceived more profitable and requiring of a higher outside technical capacity than the average BMP. Regardless, the average producer had a 0.97 probability of adopting this practice, which varied little regardless of varying the perceptions of high outside technical requirements. This result is more useful as an indicator of a practice that already witnesses high adoption, rather than as part of a strategy to increase adoption

4. Test manure, effluent, compost for nutrients – This model predicted that the average producer exhibited a 0.78 probability of adopting this practice, predicting that small operations and operations with low profit perceptions would not adopt. The probability of adoption reached 0.75 around 6,000 animals. Operations that strongly agreed that this practice required a high degree of outside assistance (Likert value of five) were predicted to adopt, but barely. Removing the perception that this BMP required outside technical assistance nearly guaranteed adoption, even for the smallest operations. Results indicated that economic constraints limit adoption by smaller producers.

5. Incorporate manure within 48 hours of application- The relatively mediocre adoption rate of 42% indicated potential to increase adoption of this practice. Colorado and Kansas practices were predicted to adopt this practice, while Iowa and Nebraska operators were not. Changing values of the remaining significant variables (EXPER and OWN) did not qualitatively impact the probability of adoption. The model predicted non-adoption for operators that perceived this practice as unprofitable or profit-neutral. This result called for further research on the profitability of this operation, implementing a cost-share or subsidy if deemed worthwhile in terms of ammonia mitigation.

6. *Collecting runoff water from buildings and pens* - This practice was best suited to medium to larger operations. All size operations had an adoption probability of greater than 0.50, but this probability increased exponentially with size, achieving a probability of 0.80 around 10,000 head. Size was the only significant variable.

7. Providing shade in drylot pens – Smaller operations with less investment capabilities were most likely to adopt, likely due to the fact that this practice involves relatively low fixed costs. Also, operations primarily focused on the feedlot operation (less diverse) were more likely to adopt. However, the model only marginally predicted adoption in the small-low invest (500 animals, $10,000 investment/yr) scenario, and in order to achieve 0.60 probability of adoption the practice needed to be small, low invest and non-diverse. Economic perceptions do not statistically influence adoption.

8. *Applying water to surface of drylot*- Colorado producers were found more likely to adopt this practice. However, this model was found to be overall insignificant.

9. *Providing bedding in drylot pens* – PROFIT, REVENUE and various future perception variables were found significant, but PROFIT was the only variable that impacted the probability of adoption. Considering that this practice had below average profit perceptions, there was evidence of an economic constraint that merits further research.

10. Remove manure from drylots more than four times per year- Colorado and Iowa producers were more likely to adopt this practice, while Nebraska and Kansas operators were not. The model indicated that this practice was best suited for medium to smaller operations, as the probability of adoption decreased linearly with size. The model predicted that the probability of adoption reached 0.70 around 15,000 head, whereas predicted a probability of 0.40 at 50,000 head. A significant relationship was found between REVENUE and CLEAN, but the magnitude of the impact on probability of adoption was inconsequential.

5.3 Future Direction

This study aimed to provide outreach professionals with a profile of ammonia BMP adoptees and factors influencing adoption decisions, based on findings from the survey sample. Two principal limitations characterized these findings. First, the low response rate limited the ability to generalize to the population of feedlot operators. Further research needs to improve the response rate, identifying issues that hindered operator participation. Potential reasons include the length of the survey and the sensitive political nature of ammonia emissions. Furthermore, dairy operations play a key role in managing ammonia emissions, yet the survey response rate for dairy operators was prohibitively low, preventing an empirical analysis similar to the feedlot analysis. This low response rate can likely be attributed to lower overall numbers of dairy operations, as well as reluctance to participate for unknown reasons. Alternatively, the data set could be calibrated to better reflect parameters of the underlying population such as size, state location or revenue.

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APPENDIX A

Table A.1 Univariate Logit Results for All BMPs Excluding Dependent Variables PROFIT, COST, TECH

	Nutrition	Bedding	Clean	Surfce	Incorp	Soil	Runoff	Test	Shade
Constant	-2.5063	0.1762	0.4529	-0.2489	1.4566	0.4218	0.7274	-1.0773	-0.3622
st. error	1.249	0.676	0.667	0.656	1.070	0.999	0.970	0.954	1.206
p-value	0.045	0.794	0.497	0.704	0.173	0.673	0.454	0.259	0.764
Invest	2.99E-06	-3.34E-06	1.54E-06	2.71E-06	1.64E-06	4.73E-06	5.45E-06	7.75E-06	-1.45E-05
st. error	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p-value	0.461	0.228	0.506	0.184	0.445	0.274	0.161	0.064	0.039
Future	-0.1962	-1.4716	-0.6197	-0.0017	0.3649	-0.3785	-0.1067	-0.4626	0.6704
st. error	0.605	0.503	0.467	0.507	0.493	0.531	0.499	0.516	0.534
p-value	0.746	0.003	0.184	0.997	0.459	0.476	0.831	0.370	0.209
State	1.2008	0.9634	0.8727	-0.9962	-1.5792	0.1162	-0.7610	0.5447	1.1706
st. error	1.105	0.628	0.615	0.605	0.760	0.897	0.910	0.871	1.127
p-value	0.277	0.125	0.156	0.100	0.038	0.897	0.403	0.532	0.299
Revenue	-0.0010	0.0003	0.0003	-0.0003	-0.0001	-0.0003	-0.0007	-0.0008	0.0008
st. error	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p-value	0.085	0.391	0.376	0.510	0.761	0.470	0.096	0.076	0.073
Exper	0.0006	-0.0004	0.0006	0.0001	0.0024	0.0011	0.0016	0.0048	0.0017
st. error	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.002	0.001
p-value	0.649	0.692	0.500	0.918	0.124	0.279	0.182	0.041	0.225
Educ	-0.0001	-0.0002	0.0015	-0.0002	0.0173	0.0002	0.0009	0.0009	0.0009
st. error	0.001	0.001	0.001	0.001	0.017	0.001	0.001	0.001	0.001
p-value	0.944	0.880	0.222	0.878	0.318	0.906	0.529	0.525	0.494
Age	-0.0003	0.0003	-0.0006	-0.0004	-0.0170	-0.0001	-0.0003	-0.0008	0.0006
st. error	0.001	0.001	0.001	0.001	0.017	0.001	0.001	0.001	0.001
p-value	0.751	0.724	0.595	0.667	0.304	0.908	0.771	0.380	0.532

Table A.1 continued									
Own	-0.0010	-2.1560E-05	-0.0017	-0.0008	-0.0012	-0.0002	-0.0016	-0.0011	0.0016
st. error	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
p-value	0.382	0.977	0.152	0.236	0.107	0.771	0.134	0.206	0.100
Sizeg	0.0018	-1.96E-05	-3.09E-05	-7.07E-06	1.63E-05	0.0001	0.0001	0.0002	-0.0001
st. error	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p-value	0.001	0.139	0.050	0.615	0.389	0.130	0.028	0.004	0.015
Diverse	-0.0004	-0.0014	-0.0001	-0.0005	0.0018	-0.0012	-0.0020	-0.0020	-0.0031
st. error	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
p-value	0.715	0.085	0.926	0.463	0.082	0.294	0.088	0.071	0.009
Crop	0.0002	-3.56E-05	-0.0001	4.73E-05	3.58E-05	0.0002	-2.05E-05	-1.09E-04	-0.0002
st. error	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p-value	0.303	0.594	0.238	0.472	0.613	0.213	0.806	0.170	0.161
Air	-1.5761	0.0007	0.0006	0.0024	-0.5673	-1.33E-05	-0.0005	-0.0003	N/A
st. error	0.860	0.001	0.001	0.002	0.561	0.001	0.001	0.001	
p-value	0.067	0.655	0.420	0.105	0.312	0.993	0.699	0.805	
Water	1.5764	0.0003	-0.0008	-0.0016	0.5676	-0.0004	0.0021	0.0006	0.0023
st. error	0.859	0.001	0.001	0.001	0.561	0.002	0.002	0.001	0.001
p-value	0.067	0.866	0.506	0.221	0.312	0.808	0.197	0.648	0.042

APPENDIX B

Table B.1 Phase I Univariate Logit Results for Dependent Variable SURFACE

SURFACE n=148	Coefficient	St. error	P-value
CONSTANT	-0.0732	0.6835	0.9147
PROFIT	0.0010	0.0014	0.4699
TECH	0.0011	0.0016	0.4976
SIZE	-8.46E-06	1.44E-05	0.5574
CROP	3.43E-05	0.0001	0.6170
COST	-0.0011	0.0018	0.5546
INVEST	0.0000	0.0000	0.1564
FUTURE	0.0794	0.5155	0.8776
DIVERSE	-0.0005	0.0007	0.4523
REVENUE	-0.0003	0.0004	0.5151
OWN	-0.0008	0.0007	0.2627
EXPER	0.0002	0.0009	0.8598
STATE*	-1.1321	0.6292	0.0720
EDUC	-0.0002	0.0012	0.8885
AGE	-0.0004	0.0010	0.6748
WATER	-0.0015	0.0013	0.2565
AIR	0.0025	0.0016	0.1087
Likelihood Ratio(LR)	11.000		
LR P-value	0.6992		
McFadden R^2	0.06		

	% Predicted	
% Actual	0	1
0	96%	4%
1	80%	20%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table B.2 Phase I Univariate Logit Results for Dependent Variable CLEAN

CLEAN n=153	Coefficient	St. error	P-value
CONSTANT	0.7573	0.7021	0.2807
PROFIT	-2.83E-03	5.20E-03	0.5870
TECH	1.64E-03	1.51E-03	0.2745
SIZE**	-3.31E-05	1.59E-05	0.0377
CROP	-5.06E-05	7.00E-05	0.4694
COST	2.96E-03	4.94E-03	0.5495
INVEST	7.31E-07	2.38E-06	0.7583
FUTURE	-0.4612	0.4866	0.3432
DIVERSE	2.80E-05	6.81E-04	0.9672
REVENUE	4.97E-04	4.14E-04	0.2292
OWN	-1.67E-03	1.19E-03	0.1582
EXPER	6.69E-04	8.93E-04	0.4540
STATE	0.6574	0.6411	0.3051
EDUC	1.59E-03	1.27E-03	0.2114
AGE	-5.50E-04	1.10E-03	0.6166
WATER	-1.51E-03	1.34E-03	0.2577
AIR	2.69E-04	7.47E-04	0.7182
Likelihood Ratio(LR)	29.466		
LR P-value	.0209		
McFadden R^2	0.14		

	% Predicted	
% Actual	0	1
0	40%	60%
1	10%	90%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table B.3 Phase I Univariate Logit Results for Dependent Variable BED

BED n=146	Coefficient	St. error	P-value
CONSTANT***	-4.8552	1.3108	0.0002
PROFIT***	1.6085	0.2794	0.0000
TECH	0.0005	0.0093	0.9563
SIZE	-1.45E-05	1.59E-05	0.3632
CROP	8.91E-06	0.0001	0.9260
COST	0.0005	0.0020	0.8124
INVEST	-1.17E-07	0.0000	0.9713
FUTURE***	-1.8187	0.6975	0.0091
DIVERSE	-0.0011	0.0010	0.2723
REVENUE	0.0004	0.0006	0.4543
OWN	0.0004	0.0009	0.6965
EXPER	-0.0012	0.0015	0.4058
STATE	0.8155	0.8400	0.3316
EDUC	0.0009	0.0017	0.5766
AGE	0.0006	0.0010	0.5480
WATER	0.0018	0.0020	0.3739
AIR	-0.0009	0.0020	0.6617
Likelihood Ratio (LR)	91.1139		
LR P-value	.0000		
McFadden R^2	0.45		

	% Predicted	
% Actual	0	1
0	78%	22%
1	14%	86%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table B.4 Phase I Univariate Logit Results for Dependent Variable INCORPORATE

INCORPORATE n=148	Coefficient	St. error	P-value
CONSTANT**	-3.8935	1.5696	0.0131
PROFIT***	1.2783	0.2487	.00000
TECH	0.0028	0.0133	0.8320
SIZE	3.28E-05	2.19E-05	0.1343
CROP	3.96E-05	8.67E-05	0.6476
COST	9.01E-04	2.03E-03	0.6577
INVEST	2.56E-06	2.61E-06	0.3259
FUTURE	0.3058	0.6092	0.6156
DIVERSE**	0.0024	0.0012	0.0435
REVENUE	-3.97E-04	0.0005	0.4245
OWN**	-0.0020	0.0010	0.0440
EXPER*	0.0031	0.0018	0.0899
STATE	-1.0849	0.9016	0.2288
EDUC	0.0092	0.0210	0.6619
AGE	-0.0101	0.0201	0.6162
WATER	0.6572	0.7200	0.3614
AIR	-0.6579	0.7200	0.3608
Likelihood Ratio (LR)	81.6580		
LR P-value	.0000		
McFadden R^2	0.40		

	% Predicted	
% Actual	0	1
0	83%	17%
1	19%	81%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table B.5 Univariate Logit Results for Dependent Variable PROTEIN, Excluding PROFIT

PROTEIN n=150	Coefficient	St. error	P-value
Constant	296.15	1007591	0.9998
COST	-0.2703	0.3105	0.3838
SIZE	1.82E-04	1.98E-04	0.3564
TECH	0.2721	0.3102	0.3816
CROP	2.20E-05	1.96E-04	0.9106
INVEST	2.96E-05	2.50E-05	0.2360
FUTURE	-0.9434	0.8474	0.2654
DIVERSE	4.72E-04	1.42E-03	0.7397
REVENUE	-2.38E-04	9.10E-04	0.7940
OWN	-0.0273	1.53E-02	0.1484
EXPER	1.16E-03	1.44E-03	0.4202
STATE	-2.93E+02	1007591	0.9998
EDUC	3.44E-03	2.29E-03	0.1340
AGE	-1.64E-03	2.06E-03	0.4269
WATER	2.7055	1.7829	0.1301
AIR	-2.7055	1.7826	0.1304
Likelihood Ratio(LR)	23.6510		
LR P-value	0.0710		
McFadden R^2	0.32		

	% Predicted	
% Actual	0	1
0	20%	80%
1	0%	100%

***significant at 1% level; **significant at 5% level, *significant at 10% level

Table B.6 Univariate Logit Results for Dependent Variable GROUP, Excluding PROFIT

GROUP n=150	Coefficient	St. error	P-value
CONSTANT	2.1350	2.6792	0.4255
TECH	-1.50E-03	0.0059	0.7983
SIZE	1.43E-04	1.13E-04	0.2073
CROP	4.37E-04	2.70E-04	0.1062
COST	4.04E-03	6.14E-03	0.5103
INVEST	6.04E-06	7.20E-06	0.4017
FUTURE	-0.5934	0.7344	0.4191
DIVERSE	3.71E-04	1.32E-03	0.7791
REVENUE	-7.30E-04	6.99E-04	0.2969
OWN	-3.04E-04	1.18E-03	0.7971
EXPER	4.13E-04	1.36E-03	0.7618
STATE	0.7298	1.2690	0.5652
EDUC	-0.1567	0.1674	0.3494
AGE**	2.47E-03	1.16E-03	0.0338
WATER	-5.46E-03	3.45E-02	0.8742
AIR	-7.29E-03	0.1305	0.9555
Likelihood Ratio(LR)	26.1450		
LR P-value	0.0365		
McFadden R^2	0.24		

	% Predicted	
% Actual	0	1
0	22%	78%
1	1%	99%

***significant at 1% level; **significant at 5% level, *significant at 10% level

APPENDIX C

Table C.1 Mean Values of Explanatory Variables for Each Ammonia BMP

Indep/Dep Variable	Nutr	Protein	Bed	Clean	Surf	Add	Incorp	Soil	Runoff	Test	Shade	Acid	Group
Profit[a]	4.1233	4.3649	3.2324	3.6803	2.8873	4.3357	3.3732	4.0207	3.0068	3.7483	3.4861	2.9516	4.1429
Tech[a]	4.2222	4.0272	1.8865	3.4792	2.1277	3.7273	2.1915	4.1736	3.1849	3.9510	2.1338	3.4390	2.0890
Cost[a]	3.0759	2.6395	3.5357	0.6738	3.4085	3.1620	3.5107	3.4825	3.9456	3.3546	3.4583	0.2500	2.1507
Air[b]	0.3237	0.3404	0.3359	0.6993	0.6204	0.2741	0.6691	0.3333	0.4014	0.4135	0.2353	0.2072	0.1460
Water[b]	0.4071	0.5035	0.3664	0.5476	0.2148	0.3209	0.7080	0.6912	0.8483	0.7226	0.1778	0.6336	0.0949
Size	6835.3	6839.5	6974.8	6703.3	6915.6	6844.7	6462.3	6740.5	6757.9	6821.3	6898.0	7380.6	6825.3
Crop	2018.0	1987.7	2039.4	1975.5	2049.0	1997.8	2016.5	2025.6	1998.0	2018.6	2001.9	2123.1	1998.4
Own[c]	64.5035	64.078	64.3841	64.604	64.424	64.7101	66.1367	65.567	64.860	65.638	64.712	64.000	65.212
State[d]	0.8933	0.9000	0.8904	0.8954	0.8919	0.8911	0.9054	0.9067	0.8947	0.9000	0.8919	0.8788	0.8933
Exper[d]	30.5799	30.350	30.6821	30.520	30.588	30.5284	30.9894	30.670	30.743	30.844	30.500	30.615	30.531
Age	55.0000	54.561	55.0149	55.267	55.095	55.0074	54.9416	54.964	54.750	54.826	54.970	55.032	55.100
Invest[d]	62208.7	61810.	58006.7	61934	62455	64137.3	62233.2	60888	62489	61893	57721	61775	61517
Future[b]	0.1933	0.1933	0.1986	0.1895	0.1959	0.1905	0.2027	0.1933	0.1974	0.2000	0.1959	0.2121	0.2013
Educ[d]	14.1958	14.208	14.2374	14.15	14.581	14.1702	14.1408	14.159	14.191	14.194	14.241	14.539	14.195
Revenue[d]	9.6250	9.5600	9.4861	9.4342	9.6174	9.7123	9.5775	9.6486	9.5811	9.6250	9.5600	9.5826	9.5600
Diverse[d]	69.1079	69.032	69.2370	68.975	68.802	69.7555	68.2353	69.036	68.829	68.597	68.952	68.143	68.744

[a] Likert Scale variable (1=strongly disagree, 5=strongly agree) [b] Yes/No variable responding to specific question; [c] Categorical variable over defined interval (see survey in Appendix E)

APPENDIX D

Table D.1 LPM Results for Dependent Variable ADD

ADD n= 147	Coefficient	St. error	P-value
CONSTANT	0.9332	6.69E-02	0.0000
PROFIT	4.75E-07	1.68E-04	0.9977
TECH	-2.82E-05	1.67E-04	0.8661
SIZE	2.24E-06	1.20E-06	0.0631
CROP	-1.41E-05	6.72E-06	0.0374
COST	-1.24E-04	1.32E-04	0.3475
INVEST	-1.57E-07	2.06E-07	0.4462
FUTURE	-1.02E-01	4.84E-02	0.0373
DIVERSE	8.66E-05	7.41E-05	0.2447
REVENUE	-8.42E-06	3.78E-05	0.8239
OWN	1.29E-04	7.04E-05	0.0697
EXPER	-6.74E-05	9.07E-05	0.4587
STATE	6.37E-02	6.20E-02	0.3056
EDUC	1.77E-04	1.16E-04	0.1273
AGE	2.03E-05	8.48E-05	0.8112
WATER	-3.55E-05	1.28E-04	0.7824
AIR	7.94E-05	1.33E-04	0.5507
Adjusted R^2	0.01		
F(16, 130)	1.33		0.3302

Table D.2 LPM Results for Dependent Variable BED

BED n=146	Coefficient	St. error	P-value
CONSTANT	0.5621	1.54E-01	0.0004
PROFIT	1.32E-04	6.56E-04	0.8413
TECH	3.49E-04	5.01E-04	0.4865
SIZE	-4.03E-06	2.68E-06	0.1346
CROP	-6.46E-06	1.52E-05	0.6715
COST	-2.53E-05	3.85E-04	0.9477
INVEST	-7.54E-07	5.28E-07	0.1558
FUTURE	-0.2884	1.10E-01	0.0095
DIVERSE	-2.54E-04	1.57E-04	0.1087
REVENUE	7.92E-05	8.99E-05	0.3799

OWN	-8.91E-06	1.69E-04	0.9579
EXPER	-4.74E-05	2.05E-04	0.817
STATE	0.1891	1.41E-01	0.1831
EDUC	-7.49E-05	2.43E-04	0.7585
AGE	8.20E-05	1.86E-04	0.6601
WATER	2.64E-05	3.54E-04	0.9406
AIR	1.20E-04	3.51E-04	0.7339
Adjusted R^2	0.14		
F(16, 129)	1.74		0.04776

Table D.3 LPM Results for Dependent Variable CLEAN

CLEAN n=153	Coefficient	St. error	P-value
CONSTANT	0.6345	1.46E-01	0.0000
PROFIT	9.82E-05	3.50E-04	0.7796
TECH	2.51E-04	3.17E-04	0.4297
SIZE	-5.25E-06	2.70E-06	0.0542
CROP	-1.31E-05	1.48E-05	0.3750
COST	1.57E-04	2.83E-04	0.5790
INVEST	1.37E-07	4.63E-07	0.7673
FUTURE	-0.1015	1.04E-01	0.3291
DIVERSE	-1.83E-05	1.52E-04	0.9041
REVENUE	9.89E-05	8.38E-05	0.2402
OWN	-2.16E-04	1.55E-04	0.1658
EXPER	1.31E-04	1.98E-04	0.5102
STATE	0.1578	1.35E-01	0.2432
EDUC	3.01E-04	2.44E-04	0.2191
AGE	-1.27E-04	1.95E-04	0.5162
WATER	-2.36E-04	2.12E-04	0.2672
AIR	-8.40E-05	2.86E-04	0.7692
Adjusted R^2	0.07		
F(16, 136)	1.74		0.0459

Table D.4 LPM Results for Dependent Variable GROUP

GROUP n=150	Coefficient	St. error	P-value
CONSTANT	0.7684	7.4800	0.0000
PROFIT	3.07E-04	5.12E-04	0.5492
TECH	-1.25E-04	3.31E-04	0.7055

SIZE	3.66E-06	1.88E-06	0.0536
CROP	1.67E-05	1.14E-05	0.1473
COST	7.13E-05	3.55E-04	0.8414
INVEST	1.72E-07	3.09E-07	0.5799
FUTURE	2.99E-04	3.84E-04	0.4370
DIVERSE	3.30E-05	1.07E-04	0.7575
REVENUE	-4.26E-05	5.60E-05	0.4479
OWN	-6.72E-05	1.05E-04	0.5219
EXPER	3.22E-05	1.36E-04	0.8131
STATE	1.59E-02	9.39E-02	0.8655
EDUC	-4.49E-04	1.65E-04	0.0074
AGE	4.44E-04	1.32E-04	0.0010
WATER	-8.92E-05	2.31E-04	0.6999
AIR	-6.12E-05	2.31E-04	0.7915
Adjusted R^2	0.04		
F(16, 133)	1.42		0.1412

Table D.5 LPM Results for Dependent Variable NUTRITION

NUTRITION n=150	Coefficient	St. error	P-value
Constant	0.6126	1.28E-01	0.0000
PROFIT	3.80E-04	4.25E-04	0.3728
TECH	2.60E-04	2.92E-04	0.3733
SIZE	5.29E-06	2.23E-06	0.0191
CROP	1.30E-05	1.27E-05	0.3098
COST	-1.80E-05	2.72E-04	0.9473
INVEST	4.52E-07	3.90E-07	0.2489
FUTURE	-5.84E-02	8.96E-02	0.5156
DIVERSE	4.48E-05	1.25E-04	0.7205
REVENUE	-1.28E-04	7.20E-05	0.0770
OWN	-1.34E-04	1.34E-04	0.3179
EXPER	1.22E-04	1.71E-04	0.4756
STATE	5.37E-02	1.16E-01	0.6450
EDUC	-1.21E-04	2.02E-04	0.5500
AGE	1.92E-04	1.54E-04	0.2161
WATER	2.45E-04	2.79E-04	0.3826
AIR	-1.23E-04	2.56E-04	0.6321
Adjusted R^2	0.10		
F(16, 133)	2.02		0.0162

Table D.6 LPM Results for Dependent Variable SHADE

SHADE n=148	Coefficient	St. error	P-value
Constant	0.4061	2.8440	0.0000
PROFIT	-2.96E-04	3.56E-04	0.4076
TECH	8.41E-05	2.51E-04	0.7386
SIZE	-5.87E-06	2.48E-06	0.0195
CROP	-1.63E-05	1.40E-05	0.2475
COST	-7.35E-05	3.52E-04	0.8347
INVEST	-1.16E-06	5.13E-07	0.0252
FUTURE	9.63E-02	9.98E-02	0.3366
DIVERSE	-4.52E-04	1.46E-04	0.0024
REVENUE	1.08E-04	8.14E-05	0.1862
OWN	2.36E-04	1.47E-04	0.1109
EXPER	1.23E-04	2.07E-04	0.5531
STATE	0.1307	0.1299	0.3163
EDUC	1.31E-04	2.49E-04	0.6005
AGE	2.17E-05	1.93E-04	0.9106
AIR	3.12E-04	1.42E-04	0.0297
Adjusted R^2	0.16		
F(15, 133)	2.82		0.0007

Table D.8 LPM Results for Dependent Variable SOIL

SOIL n=150	Coefficient	St. error	P-value
Constant	7.42E-01	0.1410	0.0000
PROFIT	4.14E-04	5.85E-04	0.4807
TECH	-2.79E-04	4.77E-04	0.5589
SIZE	3.01E-06	2.40E-06	0.2112
CROP	1.48E-05	1.36E-05	0.2780
COST	3.75E-05	2.84E-04	0.8954
INVEST	4.80E-07	4.13E-07	0.2472
FUTURE	-5.81E-02	9.41E-02	0.5379
DIVERSE	-1.16E-04	1.40E-04	0.4109
REVENUE	-4.07E-05	7.77E-05	0.6013

OWN	-4.07E-05	1.41E-04	0.7732
EXPER	1.73E-04	1.88E-04	0.3593
STATE	-4.71E-02	0.1296	0.7169
EDUC	-9.92E-05	2.53E-04	0.6952
AGE	1.02E-04	1.86E-04	0.5859
WATER	1.01E-06	2.79E-04	0.9971
AIR	-9.71E-05	2.74E-04	0.7232
Adjusted R^2	0.07		
F(16, 133)	0.62		0.8634

Table D.9 LPM Results for Dependent Variable INCORPORATE

INCORPORATE n=148	Coefficient	St. error	P-value
Constant	0.6476	0.1590	0.0001
PROFIT	-1.00E-04	6.53E-04	0.8782
TECH	5.24E-04	4.89E-04	0.2858
SIZE	3.36E-06	2.82E-06	0.2356
CROP	1.02E-05	1.51E-05	0.5032
COST	9.47E-07	3.60E-04	0.9979
INVEST	2.76E-07	4.62E-07	0.5512
FUTURE	6.50E-02	0.1015	0.5232
DIVERSE	2.96E-04	1.49E-04	0.0493
REVENUE	-4.24E-05	8.62E-05	0.6237
OWN	-2.58E-04	1.57E-04	0.1022
EXPER	2.88E-04	2.05E-04	0.1628
STATE	-0.2796	0.1461	0.0578
EDUC	5.04E-04	2.93E-04	0.0877
AGE	-5.27E-04	2.17E-04	0.0167
WATER	3.69E-04	3.41E-04	0.2811
AIR	-4.69E-04	3.86E-04	0.2265
Adjusted R^2	0.11		
F(16, 131)	2.14		0.0100

Table D.10 LPM Results for Dependent Variable TEST

TEST n=150	Coefficient	St. error	P-value

Constant	0.4935	0.1504	0.0013
PROFIT	7.19E-04	3.93E-04	0.0699
TECH	-9.72E-04	4.26E-04	0.0241
SIZE	7.21E-06	2.58E-06	0.0059
CROP	-2.56E-06	1.44E-05	0.8589
COST	6.65E-04	2.56E-04	0.0104
INVEST	8.91E-07	4.51E-07	0.0503
FUTURE	-0.1205	0.1000	0.2306
DIVERSE	-1.12E-04	1.51E-04	0.4591
REVENUE	-1.46E-04	8.22E-05	0.0774
OWN	-2.22E-04	1.53E-04	0.1482
EXPER	5.39E-04	2.17E-04	0.0144
STATE	-9.64E-03	0.1390	0.9448
EDUC	1.85E-04	2.77E-04	0.5049
AGE	-7.57E-05	2.00E-04	0.7060
WATER	1.62E-04	2.85E-04	0.5710
AIR	-2.27E-04	2.54E-04	0.3728
Adjusted R^2	0.22		
F(16, 133)	2.39		0.0036

Table D.11 LPM Results for Dependent Variable RUNOFF

RUNOFF n=152	Coefficient	St. error	P-value
Constant	0.7084	1.48E-01	0.0000
PROFIT	-3.52E-04	6.63E-04	0.5960
TECH	-8.17E-05	3.69E-04	0.8253
SIZE	5.02E-06	2.52E-06	0.0484
CROP	3.92E-06	1.51E-05	0.7950
COST	4.88E-04	5.40E-04	0.3682
INVEST	7.29E-07	4.40E-07	0.0998
FUTURE	-5.20E-02	9.92E-02	0.6011
DIVERSE	-1.99E-04	1.50E-04	0.1851
REVENUE	-1.29E-04	8.09E-05	0.1139
OWN	-2.43E-04	1.54E-04	0.1168
EXPER	2.70E-04	2.02E-04	0.1828
STATE	-0.1515	1.37E-01	0.2718
EDUC	1.05E-04	2.67E-04	0.6936

AGE	6.84E-05	1.87E-04	0.7148
WATER	3.05E-04	3.28E-04	0.3545
AIR	-5.67E-05	2.69E-04	0.8332
Adjusted R^2	0.06		
F(16, 135)	1.61		0.0710

Table D.12 LPM Results for Dependent Variable SURFACE

SURFACE n=148	Coefficient	St. error	P-value
Constant	0.4693	1.50E-01	0.0022
PROFIT	1.74E-04	2.82E-04	0.5378
TECH	1.80E-04	3.01E-04	0.5524
SIZE	-1.04E-06	2.65E-06	0.6951
CROP	6.85E-06	1.48E-05	0.6446
COST	-2.14E-04	3.63E-04	0.5570
INVEST	6.13E-07	4.72E-07	0.1961
FUTURE	1.97E-02	1.07E-01	0.8545
DIVERSE	-1.23E-04	1.55E-04	0.4279
REVENUE	-4.87E-05	8.45E-05	0.5654
OWN	-1.70E-04	1.56E-04	0.2789
EXPER	3.35E-05	2.00E-04	0.8673
STATE	-0.2379	1.38E-01	0.0882
EDUC	-2.29E-05	2.44E-04	0.9254
AGE	-8.55E-05	1.91E-04	0.6559
WATER	-2.90E-04	2.61E-04	0.2679
AIR	4.50E-04	2.87E-04	0.1188
Adjusted R^2	0.07		
F(16, 131)	0.64		0.8474

Table D.13 LPM Results for Dependent Variable PROTEIN

PROTEIN n=150	Coefficient	St. error	P-value
CONSTANT	1.0051	12.5090	0.0000
TECH	1.13E-04	2.08E-04	0.5899
SIZE	1.20E-06	1.38E-06	0.3851
CROP	1.50E-04	2.01E-04	0.4550

COST	3.03E-06	7.97E-06	0.7044
INVEST	1.72E-07	2.37E-07	0.4689
FUTURE	-0.1037	5.39E-02	0.0562
DIVERSE	3.75E-05	8.03E-05	0.6411
REVENUE	-1.24E-06	4.36E-05	0.9774
OWN	-4.90E-05	8.16E-05	0.5490
EXPER	1.08E-04	1.05E-04	0.3042
STATE	-0.0620	7.41E-02	0.4045
EDUC	1.49E-04	1.28E-04	0.2470
AGE	-1.35E-05	9.45E-05	0.8866
WATER	2.15E-04	2.01E-04	0.2861
AIR	-3.58E-05	1.77E-04	0.8399
Adjusted R^2	0.03		
$F(15, 134)$	1.33		0.1928

APPENDIX E

Producer Survey

What Can Be Learned About Best Practices for Manure Management?

A Regional Survey of Dairies & Livestock Producers

A cooperative effort of:

Colorado State University Cooperative Extension

Colorado Farm Bureau

Colorado Livestock Association

Colorado Dairy Farmers

Colorado Department of Public Health and Environment

Natural Resources Conservation Service

Colorado State University
Knowledge to Go Places

Dear Producer –

We need your help.

Dairies and feedlots are important to the rural economies of Colorado, Iowa, Kansas and Nebraska, and manure management and nutrient recycling are increasingly important to these industries as they strive for a more profitable and sustainable future. For this reason, the Colorado Livestock Association (CLA), Colorado State University Cooperative Extension, Colorado Farm Bureau, and USDA-Natural Resources Conservation Service (NRCS) have formed a team whose objective is to assist dairy and feedlot producers in choosing the best practices for manure management for their operations.

We believe that you can tell us about the best ways in which you manage nutrients and manure, as well as help us identify innovative practices which you might be interested in. We can then use this information to develop research projects as well as manure management educational programs for producers.

To get started, we need you to please help us establish a baseline of best management practices for manure and nutrient management by completing the attached questionnaire and returning it in the enclosed, postage paid envelope. It should take no more than **30 minutes** to complete.

We hope the information gained from your responses will:

- Help us assist dairy and feedlot producers in learning best management practices from each other.
- Suggest where cost sharing and technical assistance might best be targeted.
- Describe opportunities for future research.
- Provide Cooperative Extension specialists with best management information to use in their educational programs.

Your survey responses to the questionnaire are **completely voluntary** and will be held in **complete anonymity**. Information will only be reported as summary responses (e.g., averages). Because the research team has contracted the mailing of this survey through a third party, we have no way to link the survey responses to your individual information. The questionnaires are returned to us, and we will keep the responses completely confidential. The tracking code at the top of the survey will be reported to the third party mailer so that you do not receive a follow-up postcard or a second survey. The code on the return envelope is an accounting code used to charge the research team for mailing.

We appreciate your investment in the future of dairy and feedlot production!

Thank you for your time and effort in completing this survey about best management practices. If you have questions about the survey please contact Jessica Davis at (970) 491-1913 or email Jessica.Davis@ColoState.edu.

Sincerely,

Jessica Davis, Professor Troy Bredenkamp, Executive Director Bill Hammerich, CEO

Colorado State University Colorado Farm Bureau Colorado Livestock Association

Fort Collins, CO, 80523-1170 Centennial, CO 80112 Greeley, CO 80631

Section 1. Basic Production Information

This survey section is concerned with understanding the size and scope of your operation. Please fill out this section with responses that address your entire operation.

1. What feedlot or dairy enterprises did you operate in 2006 *(check all that apply)*
   - ❑ Dairy Operation
   - ❑ Cow/ Calf Operation
   - ❑ Background Calves for Feedlot
   - ❑ Develop Heifers
   - ❑ Raise Replacement Dairy Heifers
   - ❑ Fed Cattle to Slaughter
   - ❑ Other Livestock (please list)_______ ________________________________

2. On average, how many animals were in your operation for a typical day in 2006? (*write in the number*)
   - _____ Number of Dairy Cows (milking and dry)
   - _____ Number of Beef Cows/Calf Pairs
   - _____ Number of Background Calves
   - _____ Replacement Dairy Heifers
   - _____ Feeder Livestock
   - _____ Other Livestock _________________

3. If you own a dairy, what is your average yearly milk yield per cow? _______________ lbs/cow/yr

4. If you feed cattle, what is your average daily gain for feedlot cattle? _______________ lbs/hd/d

5. How large is the land area used by your livestock facilities (i.e. buildings, barns & pens)?______ acres

6. How many acres of cropland (including pasture) are used in the operation? __________ acres

7. What percent of the total cropland is owned? _____ % (*leave blank if you do not have cropland*)

8. Please indicate the state in which most of your feedlot or dairy operation is located:

   ❑ Colorado ❑ Nebraska ❑ Iowa ❑ Kansas

9. How many years have you been managing livestock? _____ years

10. What proportion of your total farm revenues come from feedlot and/or dairy production?

- ❑ 0 % to 9%
- ❑ 10% to 19%
- ❑ 20% to 29%
- ❑ 30% to 39%
- ❑ 40% to 49%
- ❑ 50% to 59%
- ❑ 60% to 69%
- ❑ 70% or greater
- ❑ Choose not to reveal

11. In the next five to fifteen years, how do you believe your operation may change? (*Please circle one choice in each column. N/A means it doesn't apply to your operation*)

Do you expect to	In the next 5 years	Between 5 and 15 years
Increase the number of livestock	YES NO UNSURE N/A	YES NO UNSURE N/A
Decrease the number of livestock	YES NO UNSURE N/A	YES NO UNSURE N/A
Invest in new buildings	YES NO UNSURE N/A	YES NO UNSURE N/A
Invest in new land	YES NO UNSURE N/A	YES NO UNSURE N/A
Retire from the operation	YES NO UNSURE N/A	YES NO UNSURE N/A

Section 2. Management Practices. Please fill out the section with "typical" management practices in mind and give your opinion about whether the practice improves profitability, if the practice requires technical assistance from someone outside the operation, if the practice is expensive, if the practice helps safeguard air quality, and if the practice helps safeguard water quality. The second part focuses on dairy management practices.

Part 1. Livestock/Land Management. *Rate according to the scale(1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree)*

Livestock Management Practices	***In your opinion,*** **is this a profitable practice?** ***(please circle)***	***In your opinion*****, does this practice require outside technical assistance?** ***(please circle)***	***In your opinion,*** **is this practice expensive?** ***(please circle)***	**Do you apply this practice?** ***(please circle)***	***In your opinion*****, does this practice safeguard AIR quality?** ***(please circle)***	***In your opinion*****, does this practice safeguard WATER quality?** ***(please circle)***
Measure and adjust dietary crude protein to meet animal needs	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Hire a nutritionist to formulate rations	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO

Use feed additives	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Practicegroup feeding (group by sex, age, etc.)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Provide shade in drylot pens	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Apply water to the surface of drylot pens	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Apply an acidifier to drylot surfaces	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Remove manure from drylot pens at least six times per year	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Provide bedding (i.e. straw) in drylot pens	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Collect runoff water from buildings and	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO

Land Management Practices						
Incorporate manure within 48 hours after application.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Test manure, effluent, or compost for nutrients	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Perform a yearly soil test for crop nutrients	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO

Part 2. Dairy Management Please fill out the section with "typical" management practices in mind and give your opinion about whether the practice improves profitability, if the practice requires technical assistance from someone outside the operation, if the practice is expensive, if the practice helps safeguard air quality, and if the practice helps safeguard water quality. ***Go to the next page if you do not operate a dairy.***

Rate the best management practices according to the scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree)

Dairy Management Practice **If you do not operate a dairy, go to the next page.**	***In your opinion,*** **is this a profitable practice?** ***(please circle)***	***In your opinion,*** **does this practice require outside technical assistance?** ***(please circle)***	***In your opinion,*** **is this practice expensive?** ***(please circle)***	**Do you apply this practice?** ***(please circle)***	***In your opinion,*** **does this practice safeguard AIR quality?** ***(please circle)***	***In your opinion,*** **does this practice safeguard WATER quality?** ***(please circle)***
Flush barns and alleyways with clean water.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Flush barns and alleyways with treated water (i.e. recycled lagoon water)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Treat recycled lagoon water used for flushing with an acidifier	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO

Use sand bedding in freestalls	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Use recycled manure as bedding in freestalls	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Cover waste lagoons	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Aerate waste lagoons	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Acidify lagoon to decrease pH	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Flush milking parlor holding area after each group of cows	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO
Flush drylot feed lanes with water	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	YES NO	YES NO

Section 4. Housing System. T*he following section pertains to your housing system. If you have a free stall system, please fill out the left-hand side of the page. If you have a drylot system, please fill out the right-hand side. If you have a mixed system (both freestall and drylot) please fill out both sides.*

IF YOU HAVE A FREESTALL SYSTEM, please fill out the following:

1. Is your freestall barn: (*check the appropriate system below*):

___ open, naturally ventilated

___ enclosed with forced ventilation

If enclosed, do you treat exhaust air (i.e filters)? (*circle*)

YES or NO

2. What is the stocking rate in your barns? _________ cows per freestall

3. What surface is used in your alleyway? (check all that apply)

- ❑ **Concrete**
- ❑ **Rubber Mats**
- ❑ **Other ___________**
- ❑ **Fly Ash**

IF YOU HAVE A DRYLOT SYSTEM, please fill out the following:

1. What type of bedding is used in drylots? (*check all that apply*)

- ❑ **Straw**
- ❑ **Corn Fodder**
- ❑ **None**
- ❑ **Shavings**
- ❑ **Wood Chips**
- ❑ **Other ______________**

2. If bedding is used, how many times is it applied per week? __________

3. When is bedding used? (*check all that apply*)

- ❑ **Spring**
- ❑ **Summer**
- ❑ **Fall**
- ❑ **Winter**

4. After removing bedding, where does it go next? (*check all that apply*)

- ❑ **Lagoon**
- ❑ **Stockpile**
- ❑ **Compost**

5. What is the typical stocking density of drylot corrals?

_____ square foot per animal (*OR*) _____ inches bunkspace per head

6. Do you separate pens by (*check all that apply)*

- ❑ **Age**
- ❑ **Health**
- ❑ **Weight**
- ❑ **Sex**
- ❑ **Dietary Needs**
- ❑ **Lactation Stage**
- ❑ **Ownership**
- ❑ **Days on Feed**
- ❑ **Avg. Daily Gain**

Section 3. Manure Management System. *This section of the survey is concerned with your primary manure storage and treatment system. Please complete each of the following questions.*

1. What type of manure management system do you use? *(check all that apply)*

- ❑ Lagoon
- ❑ Solid Separation
- ❑ Compost
- ❑ Stockpile
- ❑ Runoff Pond
- ❑ Pit
- ❑ Other (please list) ___________________ ___________________

2. ***Waste Treatment Lagoons*** **(if you do not have a lagoon system, skip to Question 3)**

a. In the lagoon system, do you use *(check all that apply)*

- ❑ Aerators (# used ______)
- ❑ Circulators (# used ______)
- ❑ Storage Lagoon
- ❑ Anaerobic Digester
- ❑ Acidification (Type used ______________)
- ❑ Anaerobic lagoon (i.e. no extra treatment)

b. How many lagoons do you have? ____________

c. What is the combined surface area of the lagoons? ____________ acres

Are these lagoons engineered/used to maximize evaporation? (*circle* YES or NO)

d. How often are lagoons emptied? every ____________ years

e. Where does the effluent go once the lagoons are emptied? *(check all that apply)*

- ❑ Field application on my land
- ❑ Commercial application on another's land
- ❑ Other __________________________________
- ❑ Trucked off by a third party
- ❑ Evaporation

f. How often is sludge removed from the lagoon? ___________ number of times per ______ (e.g. two years).

3. ***Solid Separation System*** **(if you do not have a solid separation system, skip to Question 4)**

a. What type of solid separator is used? *(check all that apply)*

- ❑ Screens
- ❑ Settling Basin
- ❑ Other (please list) _____________________________

- ❑ Belt Press
- ❑ Leaky Dam

b. What is the estimated solids removal efficiency of your solid separator? ______ % of solids removed

c. Where do you use solids? *(check all that apply)*

- ❑ Field Application
- ❑ Compost
- ❑ Stockpile
- ❑ Other ______________________
- ❑ Removed by third party

4*. **Compost System*** **(if you do not have a compost system, skip to Question 5)**

a. What type of composting do you practice?

- ❑ Forced aeration (i.e. tubes for air flow)
- ❑ Worm (i.e. vermicompost)
- ❑ Turning aeration (i.e.windrows, tractor tuners)
- ❑ Outside Contractor
- ❑ Other ____________________

b. Where do you use your compost? *(check all that apply)*

- ❑ Field Application
- ❑ Removed by third party
- ❑ Commercial use
- ❑ Other ____________________________

5. ***Runoff Ponds***

If you have runoff ponds, what is the source of influent? *(check all that apply)*

- ❑ Rain/Snow
- ❑ Building Wash Water
- ❑ I do not use runoff ponds
- ❑ Pen runoff
- ❑ Composting/Stockpile Runoff
- ❑ Other ________________________

Section 4. Optional Demographic Information: Some best management practices may be difficult to adopt because they are expensive or difficult. For this reason, we would like to know a little about your operation. Please complete the following optional questions.

1. In what year were you born? ________

2. Please check your highest level of education:

- ❑ no high school
- ❑ high school diploma
- ❑ two year/technical degree
- ❑ some high school
- ❑ some postgraduate school
- ❑ four year college degree
- ❑ postgraduate degree

3. For every $1 of gross revenues from your feedlot or dairy operation, how much is kept as profit before taxes?

- ❑ 0 cents
- ❑ 6 to 10 cents
- ❑ 15 to 20 cents
- ❑ 26 to 30 cents
- ❑ 1 to 5 cents
- ❑ 11 to 15 cents
- ❑ 21 to 25 cents
- ❑ 31 or greater
- ❑ Choose not to reveal

4. In an average year, how much of your own funds do you have available for a down payment on capital investments (e.g., new barns, equipment, additional dry lot pens, herd expansion)?

- ❑ $ 0 - $10,000
- ❑ $25,001 - $50,000
- ❑ $100,001 - $250,000
- ❑ $10,001 - $25,000
- ❑ $50,001 - $100,000
- ❑ More than $250,000
- ❑ Choose not to reveal

Thank you for completing this survey. Please write any comments you have regarding best management practices for manure management in the space below. Your ideas and comments are very important to us.