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Adoption of best management practices in the Louisiana dairy industry

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ADOPTION OF BEST MANAGEMENT PRACTICES IN THE LOUISIANA DAIRY INDUSTRY

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To the Almighty for his Love and Merci, and for being always there…

To my beloved sons, Tolotra and Tantely, for giving me the strength to continue…

And in remembrance of my parents and my sisters who passed away …

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The traditional view of the agricultural community as a good steward of the environment has been challenged by increasing concerns about the complex relationship between agricultural production activities and environmental quality. Agriculture provides a large range of products to satisfy human needs. It has also been singled out as major source of water pollution.

Largely improved surface water quality has been assessed in the U.S. since the enactment of the Clean Water Act. However, efforts to reduce water pollution continue, targeting discharges from identifiable sources of water pollution and diffused discharges from nonpoint sources. Agricultural producers are encouraged to voluntarily implement site specific management practices known as best management practices (BMPs) to reduce the delivery and transport of agriculturally derived pollutants such as sediment, nutrients, pesticides, salt and pathogens to surface and ground waters. Louisiana is not a major U.S. milk producer. However, the dairy industry represents one of the most important animal agricultural industries in the state, and the need to adopt specific practices to improve water quality has become greater in the industry.

This study examined the current implementation of BMPs by Louisiana dairy producers and investigated the likelihood of a dairy producer to adopt a conservation practice. Data for the analysis was based on a mail survey of the population of dairy producers conducted in Summer, 2001. Univariate, bivariate and multivariate probit analyses allowed for estimating the probability of a dairy producer adopting one, two or a set of BMPs, given the economic and non-economic factors hypothesized as determinant in the decision to adopt. Principal component analysis was used to reduce the number of explanatory variables needed for the multivariate probit analysis.

Findings of this study emphasized the significant influence of farm size, milk productivity per cow, frequency of meetings with Louisiana Cooperative Extension Service (LCES) personnel, and producer's risk aversion on the increased adoption of BMP. Results also pointed out the need to address the lack of information regarding the legislation and the efforts to control nonpoint sources of water pollution through the use of BMPs, and the need of expanded incentives to induce producers' adoption.

CHAPTER 1

INTRODUCTION

For years, family farms in North America have received special consideration from the public. The agricultural community has been regarded as a good steward of the environment. However, as the waves of industrialization have reached the agricultural sector, there has been more concern about the complex relationship between agricultural production activities and environmental quality. Agriculture has always been central to human existence: it provides agricultural products that satisfy human needs, as well as open space and scenery. But along with these positive contributions, agriculture also contributes to environmental problems.

Randall (1987) discussed environmental degradation due to modern methods of agricultural production. He pointed at the accelerated loss of topsoil and pollution from animal wastes, fertilizer, and pesticide residues has become widespread. Odor from concentrated livestock facilities has affected the general quality of life of rural communities. Complaints have alleged that odor contamination causes residential property-value depreciation and potentially harms other businesses[1]. Lichtenberg (2000) emphasized the harm on drinking water quality caused by nitrates and pesticides, bacterial contamination from animal wastes, and other factors.

The dairy industry is one of the most important animal agricultural industries in Louisiana. In gross receipts from animal agricultural enterprises, it ranks third to poultry and cattle production. Dairy products yielded over $96 million in cash receipts in 2000 (Appendix Table A1). Similar to other agricultural production activities, the need to adopt specific management practices in dairy production has become greater in order to improve water quality.

[1] In 1996, a group of citizens in Cass County, Illinois worried about potential odor contamination on the Christmas Tree Farm business nearby Land O'Lakes Inc. facilities. Another example is the concern of opponents to Hawakeye Farms, LLC, in Iowa about the proximity of the swine facilities to a local bakery. (Marbery, 1996).

The Louisiana dairy industry, specifically those farms in the Florida parishes[2], has been targeted in recent years as a polluter of waterways. Interest has spawned substantial research in recent years to assess the impact of dairy production on water quality in the Tangipahoa River.

This study aims to examine the current adoption of best management practices (BMPs) by Louisiana dairy producers. The conduct of univariate, bivariate and multivariate probit analysis allows for investigating the economic and non-economic determinant factors of producers' decisions to adopt one, two or a set of BMPs.

1.1. Problem Statement

Louisiana is far from being a major U.S. milk producer. In 1980, farms with milk cows in Louisiana accounted for about one percent of the total U.S. farms with milk cows. This share decreased to 0.63 percent by 2000. Average production per cow represented about 75 percent of the national level in the early 1980s, and dropped to 66 percent in 2000 (Appendix Table A2). Over the past two decades, the Louisiana dairy industry has experienced the same basic trend as in the nation, toward fewer yet larger units of production. The declining trends in the number of dairy farms, number of milk cows, total production of milk and gross farm income from dairy products are shown in Figure 1.

The number of commercial dairy farms decreased from 995 in 1981 to 448 in 2000, a drop of 55 percent. Over the twenty-year period, total milk production in Louisiana declined by 29 percent, from 996 million pounds in 1981 to 705 million pounds in 2000. Average milk production per farm increased over time, from over 1 million pounds in 1981 to approximately 1.62 million pounds in 2000. This trend was due to increases in both the average number of cows per farm, from 107 to 133, and average milk production per cow, from 9,308 to 12,155

[2] Farms in St. Helena, Tangipahoa, and Washington parishes are the most targeted.

pounds (Fig. 2). Rahelizatovo and Gillespie's (1999) analysis of changes in dairy farm size, entry and exit of farms in the Louisiana dairy industry suggested the significant role of average milk productivity per cow, debt to equity ratio, the 15-month milk diversion program (MDP) in 1984, and the dairy termination program (DTP) in 1986 and 1987 in determining the structural change that occurred in the declining production region over the past twenty years.

Along with the increased efficiency in dairy production, structural change toward larger units of production also results in the problem associated with handling and managing larger volumes of wastewater and manure generated from large facilities (Reinhard *et al.*, 1999). Improper waste management causes discharges of pollutants to surface waters through spills from waste storage structures and runoff from feedlots or cropland, and to groundwater through runoff seepage. Contaminated waters have harmful effects on drinking water supplies, fisheries, recreation and wildlife.

Hence, dairy producers in Louisiana, tending to operate larger and larger farms, face similar requirements and pressure regarding the enhancement of environmental quality as producers in other major milk producing areas. Over the past twenty years, the concentration of fecal coliform bacteria in streams and other water bodies has raised major concern in Louisiana. Findings of research on water pollution have suggested the pathogen-contaminated water supply in the Tangipahoa River, within the dairy production region, has been caused by woodland and dairy farm pastures (Drapcho *et al.*, 2001). Grazing cattle has been considered to be a significant source of fecal coliform contamination to surface waters. Best management practices (BMPs) associated with wastewater and runoff from dairy farms have been developed and promoted to reduce the volume of pollution reaching a water body and improve water quality.

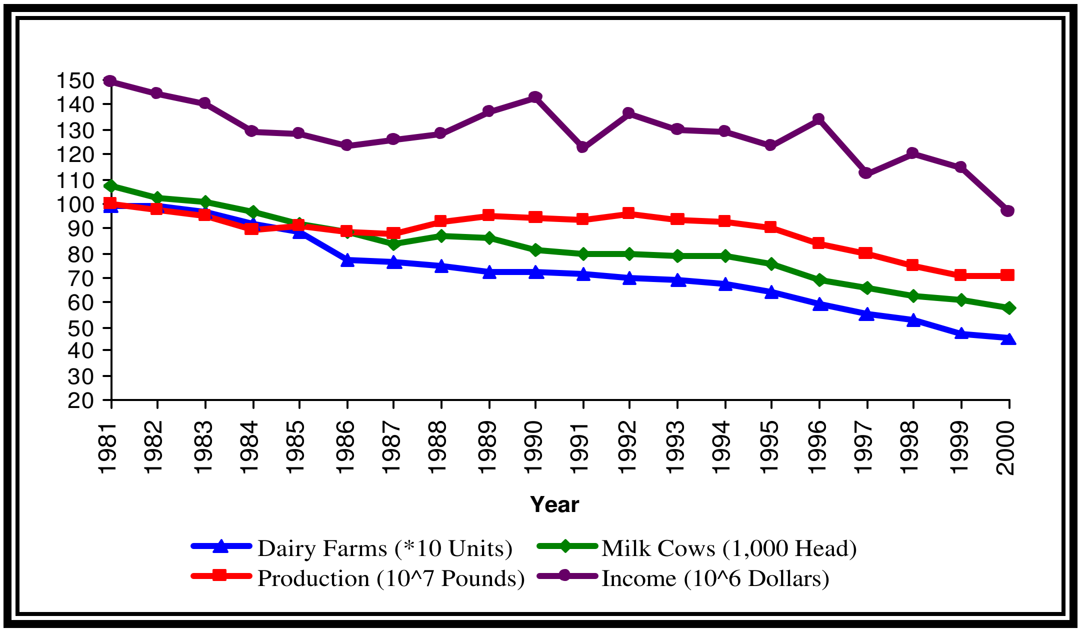

Figure 1. Milk Production in Louisiana over the 1981-2000 Period.

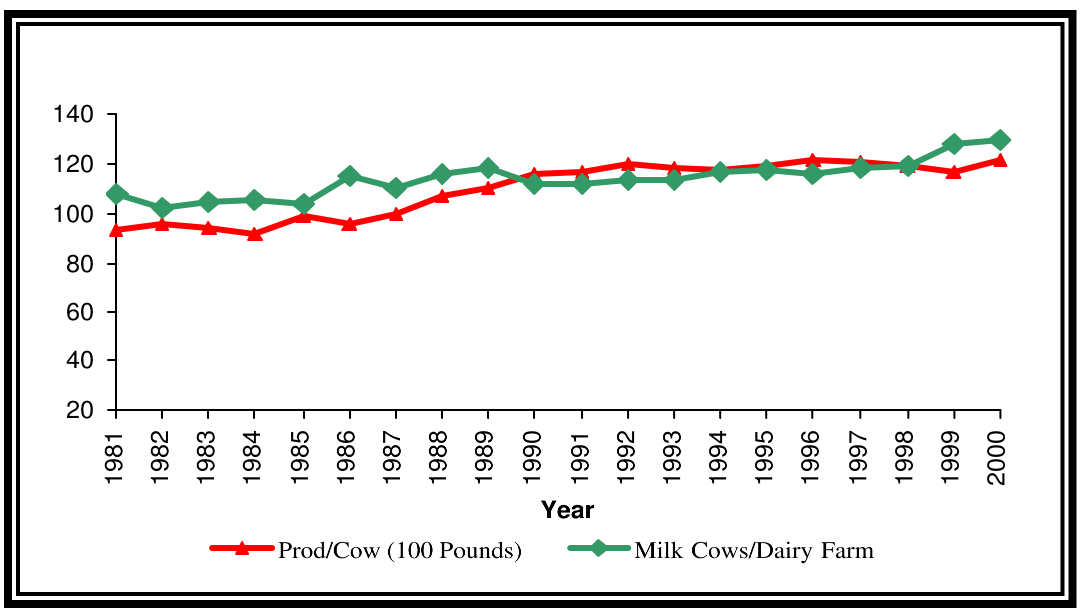

Figure 2. Evolution of Average Number of Cows per Farm and Milk Production per Cow in Louisiana over 1981-2000.

1.2. Justification

The agricultural community has traditionally been viewed as a good steward of the environment. However, there has been increasing concern about the complex relationship between farming activities and environmental quality. The significant role of agriculture as a major source of several nonpoint source pollutants such as sediment, nutrients, pesticides, salt and pathogens has been pointed out. Different studies have investigated the extent of BMP adoption in crop production since the release of the U.S. Environmental Protection Agency (EPA) guidance and specification of management measures for sources of nonpoint pollution in coastal waters, in 1993 and revised in 1997. Findings of these studies have suggested a low level of adoption of some BMPs and the need of more aggressive extension programs to convince crop producers of the benefits of implementing specific BMPs for their land.

Agricultural production is not limited to crop production but embraces diverse activities. A comprehensive understanding of the reduction of water pollution from agricultural nonpoint sources would require similar investigation conducted in crop production to be applied to other agricultural activities. Information on how other agricultural industries aim at reducing water pollution is of importance. This study focuses on the voluntary implementation of BMPs in the dairy industry. BMPs for Louisiana dairy farms target the reduction of soil, nutrients, pesticides and microbial contaminants entering surface and groundwater while maintaining or improving the productivity of agricultural land. The set of conservation practices comprises twenty one specific practices. Dairy producers are encouraged to voluntarily implement these BMPs to improve the quality of water in Louisiana. Knowledge of the current rates of adoption of BMPs as well as the types of producers most likely to adopt will allow for the implementation of extension and economic incentive programs to encourage further adoption.

1.3. Objectives of the Study

This study aims to assess the extent of current adoption of BMPs in the Louisiana dairy industry and to determine the effect of demographic, socioeconomic and farm characteristics on dairy farmer adoption of BMPs. It determines the type of producer that is most likely to adopt specific conservation practices, enabling users of the research to target specific farm types for programs to encourage the adoption of BMPs.

Specific objectives of the study include:

1. Determine the current efforts to contain water quality degradation, including regulatory measures, research and educational programs on environmental issues as they relate to Louisiana dairy production;
2. Review the literature on technology adoption in the agricultural sector;
3. Assess the extent of current adoption of BMPs in the Louisiana dairy industry;
4. Determine the effect of demographic, socioeconomic and farm characteristics on dairy producers' decisions to adopt specific BMPs; and
5. Make policy recommendations based on the empirical results.

A comprehensive review of literature on technology adoption in the agricultural sector allow for the fulfillment of objective two. The extent of current adoption of BMPs in the Louisiana dairy industry is assessed based on dairy producer responses obtained from a mail survey conducted during Summer, 2001. Producers were asked to check any of the practices they currently implement, and the possible reasons for not implementing the others.

Qualitative response econometric models are developed and analyzed to identify the variables that significantly influence dairy producers' decisions to implement or not implement a specific management practice. Univariate, bivariate and multivariate probit analyses are conducted. Univariate probit analysis focuses on current implementation of a single management practice. Bivariate and multivariate probit analyses examine the adoption of a set of two or more management practices simultaneously.

1.4. Background

1.4.1. Point and Nonpoint Sources of Pollution

Water pollution can result from two different sources. A **point source** 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). Point sources of water pollution generally originate from identifiable sites and discharge sources. These sources are subject to the permit requirements of the CWA.

A **nonpoint source** is technically defined as any other source of water pollution that does not meet the legal definition of a point source (EPA, 2000). Water pollution that results from a nonpoint source involves discharges not occurring at a single location. Nonpoint source pollution takes place in a diffuse manner and is mostly related to meteorological events such as rainfall and snow melt. Natural and manmade pollutants are carried over and through the ground and reach surface waters such as lakes, rivers, streams, wetlands and other coastal waters as well as ground water.

Studies conducted by the EPA have pointed out the gains in controlling point sources of pollution, yet the water quality problem has not been solved. Since the late 1980s, there has been a rising awareness of the significant influence of nonpoint sources of pollution that results from human activities on land. A wide variety of means carries pollutants to surface water. The EPA developed guidelines that specified different management measures for sources of nonpoint pollution in coastal waters in 1993, and a revised version of the guidance in 1997. The guidelines focused on appropriate source control measures and pollution delivery reduction in five major categories of nonpoint sources pollution: agricultural runoff; urban runoff; silviculture; marinas and recreational boating; and canalization and channel modification.

Management measures for agricultural sources aim at lessening pollution from erosion and sediment, wastewater and runoff from confined animal facilities, and better management of nutrient, pesticide, grazing, and irrigation on farm land. Management practices specific to the source of pollution, location and climate can be applied to successfully control the addition of pollutants to surface and coastal waters. Appropriate combinations of these practices, known as best management practices (BMPs), are determined to be effective and practical means to reduce water pollution from agricultural activities.

1.4.2. Water Quality Degradation

Water quality is defined according to the principal use of the resource. The CWA of 1972 describes water quality of designated beneficial uses such as drinking water supply, recreational, and aquatic life support by means of numerical criteria that set physical, chemical and biological norms, as well as narrative criteria that state the conditions required to be maintained for the designated use. Reports on water quality assessment in the U.S. indicate a largely improved surface water quality since the enactment of the CWA (EPA, 2000a; USDA-ERS, 2000). Such achievement is mainly attributed to the technology and performance based regulatory approach to reduce pollution from point sources. Assessment results also show continued discharges from point sources and an increased contribution of discharges from nonpoint sources, implying the need for a sustained effort to reduce water pollution. Reports on water quality across all water bodies indicate that, in 1998, 35 percent of assessed river miles, 45 percent of assessed lake acres, and 44 percent of estuary square miles are polluted (EPA, 2000a).

In Louisiana, the Tangipahoa River, within the dairy production region, has been subject to environmental problems from nutrient and sediment pollution, bacterial contamination from improperly functioning municipal wastewater treatment facilities, runoff and discharges from dairies and concentrated animal operations, as well as truck farming and forest harvest areas (EPA, 1995). The Louisiana Department of Environmental Quality (LDEQ) developed projects within the Tangipahoa River watershed to deal with bacterial and nonpoint source pollution, and promoted the implementation of NRCS designed lagoon systems by dairy producers in Tangipahoa parish.

1.4.3. Agricultural Pollution

Studies have pointed out the significant role of agriculture as a major nonpoint source of water pollution (EPA, 1998; Kahn, 1998; Knutson *et al.*, 1998; Ribaudo *et al.*, 1999). Pollutants that originate from agriculture include sediment, nutrients (nitrogen and phosphorus), pesticides, salts, and pathogens. Although agricultural activities are not the only source of nutrient pollutant, nitrogen from animal waste constitutes an important source of total nitrogen loads in some parts of the U.S. Similar to nutrients, pesticides move to water resources in run-off, run-in and leaching. Furthermore, they can be carried into the air and deposited to water bodies with rainfall. The possibility of pathogen-contaminated water supplies has attracted increasing attention. The EPA reports released in 1998 indicate that bacteria constitute the second leading cause in estuaries and the third leading impairment of rivers. Inadequately treated human waste, wildlife, and animal operations are identified as potential sources of bacteria. Microorganisms in livestock waste may cause several human diseases through direct contact with contaminated water or consumption of contaminated drinking water and/or contaminated shellfish.

1.4.4. Environmental Policy in Agriculture

Improving environmental quality through sustainable agricultural production is not an easy task. The questions of whether and how the government should intervene to correct environmental externalities have been discussed by many. Policy debates have been conducted and decisions made since Pigou's arguments for government intervention in the late 1930's and Coase's view of a market solution and negotiation process in the early 1960's. Pigou (1938) introduced the concept of externality taxes to eliminate the discrepancy between marginal private cost and marginal social cost. Appropriate taxes against the offending party would allow for internalizing the externality and achieving an efficient level of pollution emissions. Coase (1960), on the other hand, perceived the use of a tax as unnecessary and argued for the development of a market for the externality to achieve an optimal level of emissions, regardless of the definition of property rights. Concerned groups would negotiate to achieve a mutually profitable agreement, as long as the transaction cost is lower.

The presence and persistence of an environmental externality, however, can be attributed to market failure and therefore prevents the conduct of the Coasian market approach. Researchers have discussed different policy instruments for achieving environmental goals (Randall, 1987; Weersink *et al.*, 1997; Kahn, 1998). Governmental interventions to correct market failures associated with environmental externalities include: moral suasion, direct production of environmental quality, pollution prevention, command and control regulations and economic incentives.

Moral suasion, which consists of persuading the public about the benefits of behaving in a desired manner, has been used to influence individual behavior without specifying any rules. Its extensive use in agro-environmental policy intends to encourage agricultural operators to enhance environmental quality by adopting appropriate management practices. Yet, such voluntary approaches may not be applicable in many situations and can have limited effectiveness with the "free rider" problem. Individuals may consider their actions as minor in the collective effort. If the individual views his or her contribution as worthless, this would lead to a suboptimal provision of environmental quality in the long-run.

The second policy instrument consists of governmental programs that promote **direct production of environmental quality**. This ameliorative approach would include actions such as planting trees, stocking fish, creating wetlands and cleaning up toxic sites, and has been successful at improving environmental quality. These first two policy instruments are both appealing. However, the limited possibilities to use either have urged policy makers to develop more rigorous courses of action. **Pollution prevention** programs aim at developing more profitable and cleaner technologies. They promote the joint efforts of governmental agencies, universities, and private firms to develop research programs to reduce pollution. The efforts aim to address the lack of information associated with pollution production.

Command and control regulation is a direct control policy. It has been widely used to modify harmful behavior toward the environment by directing polluters to comply with allowable levels of pollution, and adopt the promoted type of activities or technologies to be used. Failure to adhere to such restrictions would result in penalties. Direct control policy has generally been under criticism because it may lead to greater abatement costs than necessary. Indeed, the minimum abatement costs would be achieved only if the assigned pollution levels are based on equal marginal abatement costs across polluters (Kahn, 1998, p. 62). Nevertheless, direct control constitutes an appropriate policy instrument to face emergencies and reduce environmental externalities that require high monitoring costs and/or very low optimal levels of pollution emissions.

Incentive-based mechanisms, mostly **economic incentives**, are expected to alter individual behavior and cause self-interest to agree with social interest. Individuals are given incentives to voluntarily modify their actions toward more environmentally friendly behavior. Economic instruments may include a variety of incentives such as a deposit-refund system, charges or subsidies, marketable pollution permits or transferable discharge permits, a pollution liability system, etc.

Usually, a single policy instrument does not suffice to reduce all existing environmental problems, nor is it appropriate for all situations. The effectiveness of a policy instrument in achieving environmental goals generally depends on its ability to minimize total costs of attaining the desired environmental objectives. The design of an appropriate environmental policy to reduce pollution from agricultural sources is challenging. The diffused nature of pollution emissions associated with agricultural activities rends the mission more difficult.

Programs that provide economic incentives are likely to be more successful in motivating producers. They are more flexible than command and control regulation, and allow for achieving the environmental target level at lower cost. Producers are also motivated since the cost savings form the implementation of new technology or practice accrue directly to the firm (Weersink *et al.*, 1997).

1.5. Current Programs for Controlling Agricultural Pollution

Different programs and actions have been undertaken to address agricultural point and nonpoint sources of pollution at both Federal and State levels. The EPA is the Federal authority in charge of developing policies and programs on water quality. Several environmental laws have been enacted since the Federal Food, Drug and Cosmetic Act of 1938. The Federal Water Pollution Control Act, initially approved in 1948, has been revised over the years.

The U.S. Department of Agriculture (USDA) has also provided assistance to state agencies, local government and producers to reduce erosion and chemical use in agriculture and to improve water quality since the 1930s. The Conservation Technical Program (CTP) offered technical assistance on soil and water conservation as well as water quality practices to farmers.

At the state level, farmers are given incentives to adopt management practices to reduce agricultural nonpoint source pollution. State implementation of regulations and liabilities provisions constitutes a step to move beyond a voluntary approach.

Federal and state actions targeting the enhancement of national water quality have been steady over the years. Current programs include the pursuit of existing long-term programs initiated over more than half a century ago as well as recent programs established to address specific problems.

1.5.1. Current EPA Programs

Current EPA programs targeting water quality enhancement relate to the CWA of 1977, which constitutes the primary Federal Law to address both point and nonpoint source pollution, the Coastal Zone Act Reauthorization Amendment (CZARA) of 1990 that requires specific measures for agricultural nonpoint sources of pollution, and the Safe Drinking Water Act of 1974 that establishes standards for drinking-water quality and water treatment requirements for public water systems.

The Nonpoint Source Management Program, established by Section 319 of the CWA, amended in 1987, gives EPA the authority to provide grants, program guidance and technical support for state projects promoting nonpoint source management plans and other programs. Such grants reached over $537 million in 1998 (USDA-ERS, 2000). Section 320, related to the National Estuary Program (NEP) and section 314, linked to the Clean Lakes Program, authorize USEPA to provide grants and technical assistance to states and local government for developing and implementing comprehensive conservation plans to protect and restore estuary resources and publicly owned lakes, respectively.

The Comprehensive State Ground Water Protection Program (GSGWPP), established in 1991, coordinates federal, state and local government programs addressing ground water quality. EPA also has leadership in the conduct of regional water quality programs such as: the Great Lakes Program, established in 1978 to restore and protect the Great Lakes water quality; the Chesapeake Bay Program directing the restoration of the bay since 1983 and involving the states of Maryland, Pennsylvania, Virginia and the District of Columbia; the Gulf of Mexico Program established in 1988 to protect the Gulf resources and involving the States of Florida, Alabama, Mississippi, Louisiana, and Texas; and the Lake Champlain Basin Program established by the Lake Champlain Special Designation Act of 1990 jointly administered by EPA, the States of Vermont and New York, and the New England Interstate Water Pollution Control Commission.

The CZARA remains the federally mandated program requiring specific measures for agricultural nonpoint source pollution. The program obligates each of the 29 States and territories with USEPA approved coastal zone management programs to implement their plans starting in year 2004. Annual costs of CZARA management measures are estimated to be less than $5,000 per farm (USDA-ERS, 2000).

The Wellhead Protection Program (WPP), authorized in 1986 by the Safe Drinking Water Act (SDWA), provides EPA the authority to approve state well protection programs. Forty five states had been granted EPA approved WPP programs by December 1998. Amendment of the SDWA in 1996 requires water suppliers to inform customers about the levels of certain contaminants and associated EPA standards.

1.5.2. Current USDA Conservation Programs

Conservation programs promoted by USDA are generally voluntary and provide technical, educational and financial (cost-sharing and incentive payments) assistance, rental and easement payments as well as other program benefits. In 1999, reports indicate USDA allocated $286 million for water quality and conservation activities (USDA-ERS, 2000).

The Environmental Quality Incentives Program (EQIP), initiated in the 1996 Federal Agriculture Improvement and Reform Act (1996 Farm Act), jointly administrated by NRCS and the Farm Service Agency (FSA), provides technical, educational and financial assistance to eligible farmers and ranchers in complying with federal, state, and tribal environmental laws, and encourages the implementation of conservation practices to enhance environmental quality. The program supplies up to 75 percent cost share for the implementation of conservation practices related to cropland, grazing lands and timberland such as management of grassed waterways, filter strips, and manure facilities. Incentive payments can also be extended to eligible farmers implementing practices such as nutrient management, manure management, pest management, irrigation water management and wildlife habitat management. EQIP has been reauthorized in the Farm Security and Rural Investment Act of 2002, known as the 2002 Farm Bill, with an approved funding of $6.1 billion over six years, starting with $400 million in fiscal year 2002 and increasing to $1.3 billion in fiscal year 2006 (NRCS, 2002). Changes have been made regarding its implementation. These changes include EQIP payments being made the same year as the contract approval, a one year minimum EQIP contract length, up to a 90 percent cost-share for beginning farmers and ranchers, and increased total cost-share and incentive payments to $450,000 per individual over the life of 2002 Farm Bill regardless of the number of farms or contracts. Sixty percent of the funds for EQIP are targeted to livestock production. EQIP and similar incentive programs are expected to significantly impact the adoption of environmental practices by agricultural producers.

Other USDA conservation programs are associated with crop production and land management. The Conservation Technical Assistance (CTA) program, authorized by the Soil Conservation and Domestic Allotment Act of 1935 and administered by NRCS, helps land-users in planning and implementing conservation systems to reduce erosion and improve soil and water quality. CTA provides assistance to farmers in complying with the highly erodible land and wetland provisions of the Food Security Act, as well as participant farmers in USDA cost-share and conservation assistance programs.

The Conservation Compliance Provisions enacted in the Food Security Act of 1985 require producers who farm highly erodible land to implement a soil conservation plan to remain eligible for commodity price and income support, crop insurance, and farm loan programs. The Conservation Reserve Program (CRP), established in the same Act as a voluntary long-term cropland retirement program, provides participants with annual per-acre rent and half the cost of establishing permanent land cover for retiring highly erodible and environmentally sensitive croplands for 10 to 15 years. The Conservation Reserve Enhancement Program (CREP) consists of State-Federal partnership programs targeting partial field retirement.

The Buffer Initiative established in 1997 assists landowners in installing 2 million miles of conservation buffers by 2002, and improves pollutants interception. The Wetlands Reserve Program, authorized in 1990 as part of the Food, Agriculture, Conservation and Trade Act of 1990, provides easement payments and restoration cost-shares to landowners who permanently return prior-converted or farmed wetlands to initial wetland conditions. The Small Watershed Program authorized in 1954 provides technical and financial assistance to states, local government, and other organizations that voluntarily plan and install watershed based projects on private lands. The Wildlife Habitat Incentives Program, created by the 1996 Farm Act, provides cost-sharing assistance to landowners for developing habitat for wildlife and endangered species.

1.5.3. Current Conservation Programs in Louisiana

The protection, conservation and restoration of the natural resources of Louisiana has involved the Natural Resources and Conservation Service (NRCS) through 43 local soil and water conservation districts, 7 resource conservation development areas, over 50,000 landowners, and many partners and volunteers. The team work also targets the prevention of threats to public health and the sustainability of viable agricultural enterprises. An overview of some conservation programs conducted in Louisiana is presented in the following sections.

There has been evidence of increased interest and participation of agricultural producers in the EQIP program (NRCS, 2002). The total Louisiana EQIP fund application level reached $13,947,032 over the period 1997-2000 with over 4,848 contracts funded. The 660 new contracts established in 2001 with funding of $3,188,669 involved cropland (51 percent), livestock production (47 percent), and forestland (2 percent). The total number of contracts established over the 1997-2002 period was 5,508 with a cumulative funding of over $17 million.

Louisiana has recorded 96 percent of the total Wetland Reserve Program (WRP) easements in the nation, conferring the state the lead in acres enrolled in WRP in December 2000. More than $94 million had been invested in the WRP in Louisiana by December 2000, to restore 87,102 acres in 24 parishes in the north and central parts of the state. By December 2001, the total number of WRP easements recorded had increased to 374, involving 139,801 acres of land. Over 13 thousand new acres were restored in 2001, yielding a total of 100,391 acres restored in Louisiana.

The Louisiana Grazing Lands Conservation Initiative (GLCI) constitutes a part of the voluntary nationwide effort to address owners and managers of grazing lands concern for resource needs and technical assistance. Over 4 million acres of grazing lands have been identified in Louisiana, including pastureland, rangeland, grazed woodlands, and potentially-grazed cropland. During 2000, NRCS established 8 specific projects that involved 33 livestock producers. The program aims at strengthening partnerships with the University of Louisiana at Lafayette for the completion of a dairy grazing research project, and promotes voluntary action through technical assistance for the application of NRCS prescribed grazing practices. Agricultural producers are encouraged to diversify their farming activities to achieve multiple benefits. The program provides training and education for NRCS employees as well as funding assistance to Research Conservation and Development councils for livestock educational tours. Public awareness is enhanced through the organization of workshops, field days, livestock producer meetings, and livestock publication.

A total of 2,654 contracts have been recorded in the Conservation Reserve Program (CRP) in Louisiana. The program covers 207,235 acres of land in 41 parishes, and involves total annual payments of $9,157,000 for restoring over 46,453 acres of cropped wetlands to approved bottomland hardwood and native marsh cover.

Watershed projects have promoted the reduction and elimination of flooding problems, improved water quality, and provided valuable irrigation water as well as economic development on over 5 million acres of land in Louisiana. The Watershed Program has been administered by NRCS under Public Law 83-566 since 1954. Major accomplishments have included the completion of 37 projects (9 currently active), 4 recreational areas, 11 cooperative river basin studies and the construction of dams, stabilization structures and channels with pipe drops. The USDA Emergency Watershed Protection Program provides vital natural disaster relief assistance after tropical storms, hurricanes and tornadoes. In 2001, NRCS completed emergency watershed work for damage caused by tornadoes in Webster parish, and damage caused by tropical storm Allison in East Baton Rouge parish.

Other conservation programs include the Wildlife Habitat Incentive Program (WHIP), created in the 1996 Farm Bill to provide technical assistance and cost-share payments to participants by voluntarily improving wildlife habitat on private land; the Forestry Incentives Program (FIP), authorized by the Congress to provide cost-sharing assistance for tree planting, timber stand improvement, and other related practices on non-industrialized, private forest lands; and the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA), known as the Breaux Act of 1990 and reauthorized for nine more years in 2000 to carry out high priority projects to protect and restore coastal wetlands.

1.6. Best Management Practices (BMPs)

1.6.1. Generalities

Best management practices consist of a specific set of practices determined to be effective and practical means to prevent or reduce pollution from nonpoint sources associated with agricultural activities, forestry, urban run-off, marinas, recreational boating and channel modification. Management practices are site specific. Indeed, BMPs are usually designed to control a particular pollutant type from specific land uses by minimizing the delivery and transport of pollutants available to surface and ground waters.

Implementation of BMPs is generally voluntary. However, such implementation may move toward a regulatory means of nonpoint pollution control, provided that the specified management measures are economically feasible. As Knutson *et al*. (1998) emphasized, economic incentives including conservation compliance, green payment, or regulation could improve the implementation of BMPs.

General measures for containing agricultural nonpoint sources of pollution include: control of erosion and sediment; management of wastewater and runoff from confined animal facilities[3] (large or small units); effective use of nutrients and pesticides; protecting range, pasture and other grazing lands; and managing irrigation water. A confined animal facility is described in the EPA guidance of management measures as "a facility where animals are stabled or maintained for a total of 45 days or more within any 12-month period and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility" (EPA, 1993).

[3] Management measures are relevant to all new facilities regardless of their size. They are also appropriate to existing animal facilities. Dairies with at least 70 animals, equivalent to 98 animal units, are considered as large facilities, and operations with 20 to 69 animals, corresponding to 28-97 animal units, are classified as small farms. (EPA, 1997).

The animal feeding operation (AFO) strategy, released in 1999, emphasizes the use of regulatory and voluntary incentive-based approaches to minimize water quality and public health impacts from improperly managed animal manure and wastewater, while preserving and enhancing sustainability of livestock production. AFO operators are expected to take actions to reduce water pollution by developing and implementing site-specif`ic comprehensive nutrient management plans (CNMPs). These plans include conservation practices and management activities that promote the use of manure and organic by-products as beneficial resources and lessen the adverse impacts of AFOs on water quality.

Given the controversial issues associated with concentrated animal feeding operations (CAFO)[4], specific guidance was developed in 1999 to provide information on permitting requirements for CAFOs. The CAFO designation concerns operations that confine a large number of animals and store wastewater and manure in a contained area for extended periods of time.

The AFO strategy described the two-phase approach to issue National Pollutant Discharge Elimination System (NPDES) permits to CAFOs. During the first phase from 2000 to 2005, EPA and State permitting authorities refer to existing NPDES regulations to ensure CAFO compliance with applicable water quality standards. The second phase, beginning in 2005, will consist of reissuing NPDES permits to CAFOs based on revised effluent limitation guidelines for feedlots and NPDES regulations.

1.6.2. Best Management Practices for the Louisiana Dairy Industry

A team effort led by the Louisiana State University Agricultural Center developed BMP manuals aimed at reducing the impact of agriculture on Louisiana's environment. BMPs for

Louisiana dairy farms target the reduction of soil, nutrients, pesticides and microbial contaminants entering surface and groundwater while maintaining or improving the productivity of agricultural land (LSU Agricultural Center, 2000).

Management practices targeting the reduced impacts of agriculture on Louisiana's environment include twenty one specific practices. They refer to specific NRCS codes and are implemented on agricultural land for different purposes. The description presented below was borrowed from the EPA specification of management measures and the BMP manual for dairy production in Louisiana.

Conservation tillage (NRCS Code 329) is described as a system designed to manage the amount, orientation and distribution of crop and other plant residues on the soil surface year-round. Crop residues are maintained at or near soil surfaces. Such a management system improves water flow into and through the root zone, reduces soil erosion and sediment transport by providing soil cover during critical times in the cropping cycle and influences the movement of nitrogen from the soil-plant system into the environment. Nitrogen losses associated with soil erosion and surface runoff are greatly reduced.

Cover and green manure crop (NRCS Code 340) consists of establishing a crop of close-growing grasses, legumes or small grains for seasonal protection and soil improvement. The crop is usually grown for one year or less except where there is permanent cover. This practice is designed to control erosion during periods when major crops fail to furnish enough cover. Winter cover can absorb nitrates and available water for the remaining season and therefore reduce the potential of nitrogen to leach. The cover crop, once returned to the soil,

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[4] An animal feeding operation is designated as a CAFO by the permitting authority on a case-by-case basis. CAFOs generally confine more than 1,000 animal units at the facility. The definition extends to smaller operations with 300 to 999 animal units, discharging pollutants directly into waters of the U.S.(EPA, 2000b).

provides organic materials that improve soil structure with better infiltration capacity, aeration and tilth.

Critical area planting (NRCS Code 342) involves the planting of vegetation such as trees, shrubs, vines, grasses, or legumes on highly erodible or critically eroding areas, excluding planting trees for wood products. This practice aims at reducing soil erosion and sediment delivery to downstream areas and at improving wildlife habitat and aesthetics. Plants may also take up more of the nutrients in the soil, reducing the amount of nutrients washed into surface waters or leached into ground water.

Field borders (NRCS Code 386) consist of strips of perennial vegetation established at the edge of a field to reduce erosion. Field borders serve as anchoring points for contour rows, terraces, diversions and contour strip cropping. The use of a field border may reduce the quantity of sediment and related pollutants delivered to surface waters. Other purposes include erosion control, protection of edges of fields used as turn rows or travel lanes for farming machinery, reduced competition from adjacent woodland, food and cover provisions for wildlife, and landscape improvement.

Filter strips (NRCS Code 393) are vegetative areas designed to trap sediment, organic material, nutrients and chemicals from runoff and wastewater, and thus reduce pollution and protect the environment. Implementation of filter strips relieves the problem associated with fertilizer and herbicide application close to susceptible water sources. In general, filter strip effectiveness depends on the quantity of sediment reaching the strip, the amount of time the water is retained, the infiltration rate of the soil, the uniformity of water flow through the filter strip, and the quality of maintenance.

Grassed waterways (NRCS Code 412) consist of natural or constructed channels shaped or graded to required dimensions. They are established with suitable vegetation to stabilize the conveyance of runoff from terraces, diversion or other water concentration. The design of the channel aims at reducing erosion in concentrated flow areas as well as improving water quality by filtering out suspended sediment.

Heavy use area protection (NRCS Code 561) stabilizes areas frequently and intensively used by people, animals or vehicles by establishing vegetative cover, surfacing with suitable materials, or installing needed structures. Design criteria include drainage and erosion control, appropriate structures according to engineering standards and specifications, and suitable vegetation to reduce erosion as well as air and water pollution.

Regulating water in drainage systems (NRCS Code 554) directs the operation of water control structures. This management practice is designed to regulate the outflow from drainage systems and thereby remove surface runoff. It aims at conserving surface or subsurface water and maintaining soil moisture conditions, specifically in organic soil and in highly permeable soil of low water capacity. The outflow controls should be designed based on the amount of water available and the degree of water control required.

Riparian forest buffers (NRCS Code 391) are areas of trees, shrubs or other vegetation adjacent to and uphill from water bodies. Buffer zones can be established on cropland, hay land, rangeland, forestland or pastureland neighboring permanent streams, lakes, rivers, ponds, wetlands, and other water bodies with high potential of water quality impairment. They create shade to lower water temperature and improve habitat for aquatic organisms, provide habitat and corridors for wildlife, and remove excess amounts of sediment, organic material, nutrients, pesticides and others pollutants in surface water.

A **sediment basin (NRCS Code 350)** is constructed for manure, waterborne sediment and debris storage purposes. Its design assists in maintaining the capacity of lagoons, preventing bedding materials from entering waste disposal systems, and preventing manure from moving to fields. Sediment basin capacity should be based on the expected volume of sediment to be trapped at the site.

Streambank and shoreline protection (NRCS Code 580) uses vegetation or structures to stabilize and protect banks of streams, lakes, estuaries, or excavated channels against scour and erosion. This practice applies to natural and excavated channels threatened by water erosion, livestock damage and vehicular traffic.

Roof runoff management (NRCS Code 558) deals with the collection, control and disposal of runoff water from roofs. The practice is designed to reduce erosion and pollution by preventing roof runoff water from flowing across concentrated waste areas, barnyards, roads and alleys. It is also applied for drainage improvement and environmental protection.

A **waste management system (NRCS Code 312)** is a planned system installed for managing liquid and solid waste, including runoff from concentrated waste areas. This practice is designed to preclude or minimize degradation of air, soil, and water resources, and to protect public health and safety. The system may consist of a single component or several components such as waste storage ponds, waste storage structures, waste treatment lagoons, waste utilization.

A **waste storage facility (NRCS Code 313)** consists of a waste impoundment made by constructing an embankment and/or excavating a pit, or a structure. The construction is designed for temporary storage of wastes such as manure, wastewater and contaminated runoff. The standard establishes the minimum acceptable requirements for planning, designing, constructing, and operating waste storage facilities including waste storage tanks, waste stacking facilities and settling basins, but excluding waste treatment lagoons.

A **waste treatment lagoon (NRCS Code 359)** is a waste impoundment made by excavation or earthfill for temporarily storing and biologically treating organic wastes from animal and other agricultural activities. Standards for waste treatment lagoons differ from those for waste storage ponds and waste storage structures. Lagoons must be located near the source of the waste, far from neighboring dwellings (a minimum distance of 300ft) and water wells (a minimum distance of 150 ft), and where prevailing winds carry odors away from residences and public areas.

Waste utilization (NRCS Code 633) involves the use of wastes from agricultural and other activities on land in an environmentally acceptable manner. This practice aims at maintaining and/or improving soil and plant resources. Wastes are safely applied on land and vegetation suited to the use of waste as fertilizer. Implementation of this practice is expected to enhance crop, forage and fiber production, improve or maintain soil structure, prevent erosion and protect water resources.

Nutrient management (NRCS Code 590) addresses the need for managing the amount, form, placement and timing of the application of plant nutrients associated with organic waste, commercial fertilizer, legume crops and crop residue. Comprehensive nutrient management plans are developed to realize optimum forage and crop yields, minimize nutrient entry to surface and groundwater, and maintain and/or improve the soil chemical and biological conditions. Planning considerations include a thorough evaluation of soil nutrient needs, an inventory of nutrient supply, an assessment of nutrient balance, and monitoring procedures.

Pest management (NRCS Code 595) concerns the management of agricultural pest infestations including weeds, insects and diseases, coherent with crop production and environmental standards. The development of a pest management program promotes appropriate cultural, biological, and chemical controls and includes planning considerations such as pest management procedures, pesticide selection and application, and storage and safety measures. Agricultural producers are urged to follow extension recommendations to ensure proper usage of pesticides.

Fencing (NRCS Code 382) can be used as part of a conservation management system to address soil, water, air, plant, animal and human resource issues. A constructed barrier is built to control and/or exclude livestock or wildlife and regulate human access. Plans for fencing along waterways should include crossings over waterways and provisions for animal drinking water sources.

Prescribed grazing (NRCS Code 528-A) is applied as part of a conservation management system to improve and maintain controlled harvest of vegetation for grazing animals, and enhance the quality and quantity of water and soil conditions in the area. The establishment of a prescribed grazing plan should include considerations of the duration, intensity, frequency, and season of grazing to enhance nutrient cycling and minimize soil compaction, and the needs of other enterprises such as wildlife and recreational uses.

A **trough or tank (NRCS Code 614)** provides livestock watering facilities at a selected location that will protect vegetative cover. Watering facilities are supplied by streams, springs, wells, ponds and other sources. This practice permits a desired level of grassland management, reduces health hazards for livestock and prevents livestock waste in streams.

1.7. Dissertation Outline

The dissertation is organized into five chapters. The second chapter consists of a review of relevant literature to the research problem. The third chapter focuses on data collection, the theoretical framework and research methodology. Discussion about the implementation of the mail survey, the conduct of principal component analysis to reduce the number of explanatory variables in the bivariate and multivariate probit analysis, and the different tests included in the study are provided. Descriptive statistics from the survey on Louisiana dairy producers along with the empirical results of the analyses are presented in the fourth chapter. The last chapter provides a summary and the conclusions of the study as well as some suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

This chapter consists of three major sections. Section one concentrates on selected literature related to technological adoption in the agricultural sector. Section two presents a review of selected empirical studies on conservation adoption over the past two decades. The last section focuses on environmental attitude.

2.1. Technology Adoption in the Agricultural Sector

One of the earliest studies on technology adoption was Griliches' exploration in 1957 of the economics of technological change, specifically the wide differences in the rate of use of hybrid seed corn. His interests led to investigation of the possibility that one can perform an economic analysis on the process of innovation, and the adoption of a particular invention. He emphasized the differences between the lag in "availability" due to the time-lag in the development of adaptable hybrids for specific regions, and the lag in "acceptance" perceived in the different rates of adoption by farmers, although both can be explained on the basis of varying profitability of entry. He estimated the rate of acceptance along with other parameters for each of 31 states and 132 crop-reporting districts within these states. A logistic growth curve was assumed, based on the graphical analysis of the state data on percentage of hybrid corn planted over time. An S-shaped trend was found.

Average corn acres per farm, average difference between hybrid and open pollinated yields and pre-hybrid average yield were included in linear and log regression estimations to explain the farmer's rate of acceptance. Results showed the substantial influence of the differences in profitability from shifting to hybrids on adoption. Since the publication of Griliches' work, the economics of technology adoption has captured researchers' interests, yielding hundreds of publications. Selected literature of relevance to the present study is presented in the following sections.

Feder *et al.* (1985) reviewed theoretical developments and empirical studies on adoption of agricultural innovations in developing countries. The survey showed the dependency of observed diffusion patterns on complex relationships between factors such as risks associated with the new technologies, farmers' attitudes toward risk, fixed adoption costs and cash availability. The authors discussed the variables often hypothesized by a number of empirical studies to influence farmers' adoption decisions. These variables account for farm size, risk and uncertainty, human capital, labor availability, credit constraints, supply constraints, and landownership and rental arrangements. Feder *et al.* pointed out the tendency of empirical studies to consider innovation adoption in dichotomous terms, and the need for appropriate econometric tools to allow for the simultaneous nature of adoption decisions when farmers are presented a set of new practices with various degrees of complementarity.

Caswell and Zilberman (1985) examined the determinant factors in the adoption of furrow, sprinkler, and drip irrigation by fruit growers in the San Joaquin Valley of California. Land shares of each technology type and for each region were included as estimates of adoption probabilities in a multinomial logit model. Reliability of the results was assessed based on four measures: the value of the log-likelihood function, McFadden and Efron R^2 estimators, and the percentage of correct predictions. This study emphasized the significant role of economic considerations in determining farmers' adoption of new irrigation technologies in California, and the substantial water saving from water-price policies. An increase in a water tax would encourage fruit growers to adopt modern technologies associated with water cost-saving. Such a decision would lead to a decrease in water use.

Shields *et al*. (1993) performed a longitudinal analysis of factors influencing increased technology adoption in Swaziland maize production. Their study provided insight into the adoption process shaped by different factors and endowments such as farm size, farm labor, input and output prices, capital availability, education, risk and uncertainty, and draft animal ownership. Recommended farming practices included improved seed varieties, tractor plowing, chemical fertilizers, and insecticides. A logistic model was applied to examine the probability that a maize farmer would increase application rates of a selected technology over time. The analysis was based on data collected from three surveys (in 1985, 1988, and 1991) of 85 households. Results showed the significant influence of four factors on maize farmers' decisions to adopt new technology: farmers' ability to mobilize sufficient labor, the availability of capital, farm size and risk aversion. The lack of cash would reduce the use of hybrid seed, basal and top dressed fertilizer. Certainty in the expected rainfall, associated with higher anticipated output levels would encourage farmers to adopt new technology.

Ghosh *et al.* (1994) investigated the effects of technical efficiency and risk attitudes on the adoption of artificial insemination (AI) and/or computerized dairy herd inventory accounting (DHIA) technologies in the U.S. dairy industry. The study was based on a two-step process. First, individual firms' technical inefficiencies were estimated using the stochastic production frontier approach. Then, multinomial logit analysis was used to model technology choice. Firms' technical inefficiencies and producers' risk attitudes were included as explanatory variables in the logit analysis. The theoretical model assumed farmers' knowledge of input and output prices and acknowledged the risky aspect of technology adoption. Given the stochastic nature of agricultural output, farmers would maximize expected utility, and would consider both expected profit and variance of profit. Farmer's risk attitude was assessed through participation in government-program crops, off-farm income and insurance purchase on dairy assets. All three variables were expected to have a negative sign in the multinomial logit model. The findings of the study based on 145 cross-sectional data from the Appalachian dairy region suggested significant effects of technical efficiency, milk prices and farmer's risk aversion behavior in the simultaneous adoption of both technologies.

Zepeda (1994) examined simultaneity of technology adoption and productivity in her assessment of the determinants of DHIA technology adoption by California dairy farmers. She emphasized the need for consistent and asymptotically more efficient generalized probit results that would account for the joint determination of productivity and technology choice and avoid biased estimates obtained from a single-equation. She considered a simultaneous system of structural form equations, as well as generalized probit ordinary least squares and generalized probit generalized least squares estimations to analyze 153 observations obtained from a telephone survey of randomly selected California Grade-A milk producers. The findings of the study suggested the need to correct for simultaneous equation bias in the investigation of technology adoption. Single-equation estimates would lead to overstated significance of the relationships as well as different conclusions concerning the factors affecting the decision to adopt. The model, however, suffered from a high degree of multicollinearity, affecting the significance of the coefficients.

Dorfman (1996) modeled the multiple adoption decisions of U.S. apple growers over two technologies in a joint framework, given the fact that it is essential to understand multivariate adoption decisions. Apple growers' adoption decisions on integrated pest management practices (IPM) and improved irrigation techniques were examined using four technology-bundle choices: neither technology; integrated pest management only; improved irrigation only; and both technologies. Analysis based on the four possible related choices was expected to provide a better understanding of the characteristics associated with technology adoption and an improved forecast ability. Farmers' decisions to adopt were analyzed using a univariate probit model for each technology and a multinomial probit model to account for the interrelationships among decisions. A Bayesian approach using Gibbs sampling was developed to address the computational problem associated with the maximum likelihood estimation of the n-dimensional cone integrals in the multivariate normal distribution. Findings of the study suggested a 60.3% accuracy rate of prediction (adoption decision correctly predicted). Results showed the importance of education level and the amount of off-farm work on the farmer's decision to adopt. A strong negative covariance was found between adoption of IPM and improved irrigation, challenging the tendency to believe that farmers who adopt advanced technologies necessarily tend to adopt many of them. The study suggested that IPM practices and improved irrigation techniques were not adopted simultaneously by the same farmers.

El-Osta and Morehart (1999) investigated the effects of herd expansion and other factors on dairy farmer decisions to adopt a capital-intensive and/or a management-intensive technology. Based on national data from the 1993 USDA Farm Costs and Returns Survey, the authors estimated a multinomial logit model to illustrate the economics of choosing among four types of technologies: a capital-intensive technology (an array of advanced milking parlors); a management-intensive technology (the Dairy Herd Improvement production record keeping system); a combined adoption of both technologies; and the choice of neither. Findings of the study suggested a significant role of educational attainment, farm operator's age, ownership of land and farm size in the choice and adoption of technology. Alternative simulations were run using the estimated coefficients and different farm sizes in order to assess the effects of farm expansion (doubling or tripling farm size) on the likelihood to adopt a technology. The pattern of adoption was found to be sensitive to herd expansion, which supports the idea of scale-biasedness in technology adoption. The authors concluded that benefits from farm expansion and technology adoption would remain possible providing that the purpose would be to lower per-unit costs through enhanced production efficiency rather than solely increasing per-cow yields.

Reinhard *et al*. (1999) analyzed the technical and environmental efficiency of Dutch dairy farms. The study was based on production activities of 613 strongly specialized dairy farms in the Dutch Farm Accountancy Data Network over the 1991-1994 period. The authors estimated a stochastic translog production frontier using a single index of dairy farm output, and three categories of aggregate inputs including LABOR, CAPITAL, and variable INPUT. Nitrogen surplus from application of excessive amounts of manure and chemical fertilizer was also included as an environmentally detrimental input. The derived output-oriented measure of technical efficiency was computed as the ratio of observed level of output to maximum feasible output. The authors estimated the environmental efficiency associated with each farm using the "+ V formula" based on the assumption that a technically efficient farm is necessarily environmentally efficient. Findings of the study emphasized the generally high levels of technical efficiency (89 to 90 percent on average) and the low levels of environmental efficiency (44 percent on average although steadily increasing over the sample period) achieved by the Dutch dairy farms. The estimated shadow prices of nitrogen surplus of 3.1 1991 guilders per kilogram of nitrogen surplus could provide the Dutch government information on appropriate taxes on nitrogen surpluses. Results also emphasized the weak positive relationship between environmental efficiency and intensity of dairy farming.

Davis and Gillespie (2000) examined technology adoption in U.S. hog production. Their focus was to determine the impact of financial, demographic, and structural variables on the adoption of four breeding practices and five production management practices in the hog industry. The effects of twenty-two identified explanatory variables on the decision to adopt specific technologies were assessed using a binomial logit analysis and 1025 observations obtained from a national mail survey. The influence of financial and socioeconomic aspects on the biosecurity of the operation was also examined using a two-limit tobit model. The findings of the study, consistent with the results in previous publications, supported the notion of scale-biasedness in favor of larger firms in the adoption of most of the technologies and managerial practices considered in the analysis.

Moser and Barrett (2002) investigated the complex dynamics of smallholder technology adoption of rice producers in Madagascar. They examined the potential determinants in the farmer's decision to adopt a high yielding and low external input technology known as system of rice intensification. They proposed a framework that took into account the importance of time and experience in learning a new method, the critical constraints on family labor and seasonal liquidity, as well as the possibility of nonmaterial preferences. Results of the study based on quasi-panel data and recall data related to 317 households in five villages emphasized the key roles of learning effects, financial constraints and labor availability in farmers' decisions to experiment with and adopt a new technology.

2.2. Empirical Studies on Conservation Technologies

Conservation technologies or practices considered in this section include environmentally-sound technologies, which differ from other technologies implemented in the production process. Selected literature is presented.

Gould *et al.* (1989) investigated the role of farm and operator characteristics in conjunction with the perception of soil erosion in understanding the adoption and use of alternative tillage practices by Wisconsin farmers. Their analysis, based on the 1987 Wisconsin Family Farm Survey (WFFS), involved two stages. The first stage examined the producer's level of awareness of soil erosion. The binary dependent variable, PERCEIVE, was set to one if the farm operator strongly agreed that soil erosion was an important problem in the area, and zero otherwise. The second stage analyzed farmers' adoption of conservation practices. The farmer's perception of soil erosion was derived from the probit analysis in the first stage. Then, predicted perception was included as a determinant of the farmer's adoption decision in the two-limit tobit analysis in the second stage. Findings of the study emphasized the importance of land slope steepness and contact with the Soil Conservation Service on farm operators' awareness of soil erosion problems in their area. Results also suggested that younger farmers operating larger farms were more likely to adopt soil conserving technologies, and reliable information gathering and dissemination systems could improve the effectiveness of voluntary adoption programs.

Barbier (1990) analyzed the farm-level economics of soil conservation in the uplands of Java, Indonesia, and concentrated on farmers' decisions to invest in the control of soil loss and land degradation. The upland conservation technical packages include construction of bench terraces in areas of up to 50 percent slopes in conjunction with improved cropping patterns, and agro-forestry-based systems on areas with greater slopes. Results of the study suggested that the farmer's decision to adopt a soil conservation strategy was influenced by the correlation between land erodibility and profitability of different farming systems on different soils and slopes. Furthermore, appropriate economic incentives would likely provide farmers with motivation to adjust their land management practices and farming systems.

Govindasamy and Cochran (1995) used an integrated approach to analyze the economics of the conservation compliance program and adoption of five best management practices in Iowa. The management practices included fall plow, spring plow, and conservation tillage with 20 percent, 30 percent, and 40 percent crop residues. The authors developed a linear programming model to analyze three scenarios related to a typical 350-acre Iowa farm and 12 selected soil types and percent slopes: Marshal (5 to 10 percent); Monoma (5 to 10 percent); Kenyon (2 to 5 percent); Kenyon (5 to 10 percent); Tama (2 to 5 percent); Clarion (2 to 5 percent); Clarion (55 to 10 percent); Downs (5 to 10 percent); Fayette (5 to 10 percent); Otley (2 to 5 percent); Galva (5 to 10 percent); and Sharpburg (2 to 5 percent). Marginal values of different soil types were obtained from the efficiency analysis of the Conservation Compliance Program (CCP). Govindasamy and Cochran suggested that society could benefit from farmers greater compliance to the program if marginal values of soil were equal across different types of soil. A higher net return from compliance also would enhance farmers' motivation to adopt management practices.

Lynne (1995) attempted to modify the neo-classical approach to technology adoption with behavioral science models in his examination of water conserving technology adoption behavior of Florida strawberry growers. He suggested the need for a multiple-utility framework similar to the one in the theory of planned behavior model. In this model, behavior or intention to act was determined by three components: the "I-utility" that reflects the producer's self-interest; the "We-utility" that accounts for the commitment, meta-preferences or moral dimensions; and the perceived behavioral control reflected in capital constraints and the producer's profit maximizing behavior. Tobit regression analysis was performed based on data obtained through personal interview of 44 strawberry growers. Three different scenarios were estimated depending on the type of utility considered: the mono-utility model (producers' utility uniquely from profit maximization); the profit seeking and I-utility model; and all three types of utility. Results of the study suggested that behavior in conservation technology adoption would be more than a strictly profit driven phenomenon.

Krause and Black (1995) evaluated the joint effects of machinery replacement decisions, learning curves and risk aversion on optimal adoption strategies for no-till technology[1] in Michigan, using two normative dynamic analyses. Optimal machinery selection and acquisition strategies for a representative expected profit-maximizing farmer, and a representative risk-averse, expected utility-maximizing farmer were analyzed through separate dynamic programming models. A deterministic model with maximization of time-discounted net revenues was used for the first type of farmer. A stochastic model with maximization of a time-discounted, semi-log expected utility function of net income was estimated for the second type of farmer. Key parameters assumed in determining adoption strategies included crop yields, crop prices, input costs, tractor and planter costs, tractor and planter residual values, and the discount rate. The Markovian probabilities of price were included as additional parameters for the stochastic model. Findings of the study emphasized the effects of planter age, current tractor age, relative yield expectations, risk aversion, crop price expectations, the learning curve, and the discount rate on the optimal time to adopt no-till technology. Results suggested that adjustment costs and risk aversion could substantially delay adoption. Learning curve effects and risk aversion would prevent adoption of no-till technology in the case of unfavorable crop price expectations.

Westra and Olson (1997) investigated the adoption of conservation tillage practices by farmers in two counties in East-Central Minnesota, and emphasized the importance of factors

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[1] No-till technology has been promoted for reducing soil erosion and production costs (Krause and Black, 1995).

such as information availability, consistency and relevance especially to local area, and the existence of a support system or resources in the farmer's decision process. Better quality of information would enhance producers' willingness to adopt conservation tillage practices whereas the degree of support resources available would affect their ability to implement the practice. The effects of hypothesized determinants of producers' adoption decisions were estimated using five logistic models: a base model that included the complete set of 25 explanatory variables and four parsimonious models derived from the base model. The overall findings of the study are consistent with previous research conclusions. Operators of large-sized farms, more concerned about soil erosion issues on their land, engaged in a recent major farm investment, or primarily informed about the practice by other farmers were more likely to adopt conservation tillage practices. In this study, farmers' experience was not found to be a significant factor in the adoption decision.

Cardona (1999) assessed the feasibility of alternative approaches to meeting agricultural nonpoint pollution control standards for sugarcane in Louisiana's coastal zone management areas. The study hinges on the neoclassical analysis of behavior which emphasizes individual preferences, rational economic behavior and utility maximization as well as the analysis of producers' attitudes. Sugarcane producers' adoption of best management practices (BMPs) was hypothesized as being determined by different economic, socioeconomic, institutional and attitudinal variables. Univariate probit and multivariate probit estimations to account for the contemporaneous disturbances between the adoption of specific management practices were analyzed based on 223 observations obtained from a mail survey of Louisiana sugarcane producers in 1999. The findings of the study suggested a significant influence of number of times producers met with extension service personnel, number of grower-meetings attended, participation in cost-sharing, farmers' beliefs of agricultural activities reducing the quality of water coming off farmland, level of debt, and land tenure.

Soule *et al.* (2000) explored the relationship between tenure and adoption of conservation practices. Logit regression models for conservation tillage and medium-term practices[2] were estimated, based on data from the 1996 Agricultural Resource Management Study survey administrated by NASS and the NCRS-Oregon State University PRISM project. Farmers were assumed to maximize private returns (present value of current net returns and terminal land value). The base model included farmer attributes, attributes of the farm, variables specific to the field, regional attributes and a dummy variable for tenure. Two dummy variables for cash-rented and share-rented arrangements substituted for tenure variable in a modified model. Findings of the study suggested that land tenure, timing of benefits, and land erodibility were influential factors in a farmer's decision to adopt conservation practices. Although all tenure types adopted medium-term practices, cash-rent farmers were more likely to adopt conservation tillage.

Ipe *et al.* (2001) simulated a Group Incentive Program to encourage farmer adoption of BMPs for the Lake Decatur watershed in Central Illinois. The program promoted farmers' participation in changing the timing of fertilizer application and reducing the application rate. Financial incentives were considered as necessary to ease farmers' skepticism about the profitability of implementing these practices and to promote adoption. The model was based on long-run group average profits received by both participating and non-participating farmers. An incentive payment scheme was proposed to compensate farmers participating in the program for

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[2] Medium-term conservation practices included contour farming, strip-cropping, and grassed waterways. Adoption of any of these practices would require several years to generate positive benefits, while cost savings from conservation tillage would increase profits in the short-term.

eventual losses in profits, so as to receive at least the same level of profits as non-participating farmers. Four alternative scenarios[3] were simulated. Results of the study supported a lower expected total profit for non-participants in all alternative reductions in nitrogen application. Moreover, participants in the simulated program would achieve higher expected profits even without an incentive payment. This would suggest a risk-averse farmer might be better off by participating in the Group Incentive program, because current application of nitrogen fertilizers could already be at rates above profit-maximizing levels. Thus, the proposed program would increase farmers' profits, reduce the variance of farmers' profits, and mitigate nitrate pollution in Lake Decatur.

Soule (2001) investigated the hypothesis that small farmers are better stewards of land than larger farmers in her analysis of the adoption of six nitrogen management practices and five soil management practices by U.S. corn producers in the 16 major corn producing states.[4] Nutrient management practices would lower the cost of fertilizer applications and reduce nitrate leaching and denitrification. Soil management practices, on the other hand, would reduce soil erosion and runoff and increase infiltration. A logit model was considered to analyze the factors associated with adopting a technology, based on data from a completed survey in Fall, 1996, and a Spring follow-up survey on farms that raised corn. The findings of the study suggested an equal likelihood of all types of farmers adopting soil and nutrient management practices and did not support the hypothesis of small farmers practicing better land husbandry than larger farms. College education, cash grain farming and highly erodible land variables positively affected the

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[3] Scenario 1: 75 percent of total nitrogen applied in fall and 25 percent applied in spring;
Scenario 2: 50 percent of total nitrogen applied in fall and 50 percent applied in spring;
Scenario 3: 25 percent of total nitrogen applied in fall and 75 percent applied in spring; and
Scenario 4: 25 percent of total nitrogen applied in fall, 50 percent in spring and 25 percent as side dressed.

[4] Major Corn producing states include Iowa, Illinois, Indiana, Kansas, Kentucky, Michigan, Minnesota, Missouri, North Carolina, Nebraska, Ohio, Pennsylvania, South Carolina, South Dakota, Texas, Wisconsin (Soule, 2001).

adoption of conservation tillage. Owner-operators with fewer years of farming experience would be more likely to adopt grassed waterways in areas with higher precipitation and lower temperatures.

Cooper (2001) developed a joint framework for analyzing farmers' perceptions of the desirability of adopting a bundle of environmentally benign management practices, known as best management practices (BMPs), providing the amount of payment and the types of practices offered by the Environmental Quality Incentives Program (EQIP). The author used a multinomial probit model to analyze the simultaneous discrete choice adoption decisions over five management practices: conservation tillage; integrated pest management; legume crediting; manure testing; and soil moisture testing. The study was based on dataset from surveys of over 1,000 farmers located in four U.S. regions: the eastern Iowa; the Illinois basin area; the Albermarle-Pamlico drainage area; and the Upper Snake River basin area in Idaho. The multiple-bounded approach allowed for accounting for both current users of BMPs without an incentive payment and hypothetical farmers' decisions to adopt BMPs providing the cost-sharing payment based on the survey. The bid offer in the willingness to accept (WTA) survey question was included as a factor explaining the joint probability to adopt a bundle of BMPs. Findings of the study suggested producers perceptions of BMPs as jointly beneficial or bundled. Thus, the identification of such bundles of BMPs would greatly increase the adoption and lower the cost of voluntary adoption programs.

2.3. Environmental Attitude

The increased loss of environmental amenities as well as the reduced capacity of the natural world to assimilate wastes has raised public awareness and support for environmental protection. Although many agree on the need to protect the environment, views differ on how to do so. Individuals with a more anthropocentric belief (as most neoclassical economists would be) would view an environmental problem as more of a technological problem and advocate greater efficiency in consumption and production. Those with a new environmental paradigm worldview, on the other hand, would acknowledge the reality of growth limits and the fragility of nature's balance. These persons would actively support efforts to lessen the harmful effects of human interactions with the environment. Researchers have investigated the different aspects of increased environmental concern. Some have examined the conceptualization and measurement of environmental attitude by means of attitude-measurement instruments. Others have examined the likely determinants of individual and social views of the environment.

Dunlap *et al.* (1978 and 2000) proposed and refined a measuring instrument of pro-environmental orientation, termed as the new environmental paradigm (NEP) scale. The construct of the NEP scale was based on beliefs about the nature of the relationship between earth and humans. As with many social attitude measurements, the NEP scale attempted to locate the individual's position on an affective continuum, from a "very positive" to a "very negative" attitude toward the pro-ecological view. The pool of items that formed the basis of the construct scale included a set of 12 statements in the 1978 version of the NEP scale, and extended to 15 statements in the 2000 version. Such change was intended to improve the balance between pro- and anti-NEP statements and broaden the scale content as well. Thus, the 15 statements were designed to elicit diverse opinions on five hypothesized features of an ecological worldview: the reality of limits to growth, the anti-anthropocentrism view, the fragility of nature's balance, the rejection of human exemptionalism, and the possibility of an ecological crisis. Moreover, the statements were worded in such a way that agreement to the eight odd-numbered items and disagreement to the seven even-numbered ones would denote a pro-ecological worldview. The validity and reliability of the NEP scale has favored its extensive use in many environmental studies.

Pierce *et al.* (1987) compared the effects of shared forces of post-industrialism on belief structures in nations with distinct cultural, political and historical backgrounds, and focused on the case of Japanese and American elites and the public. The authors considered twenty specific belief system elements aggregated into four categories: environmental policy variables; traditional political variables; postindustrial variables; and policy relevant knowledge. The postindustrial category included an NEP scale variable derived from responses to six of the item statements developed by Dunlap and Van Liere in 1978. Results of the analysis emphasized the persistence of cross-national differences in elites belief systems in both countries. They also highlighted the fact that political culture and social stratification are important in shaping the nature of aggregate belief systems of a country.

Arcury and Christianson (1990) examined the effects of major environmental events in 1988 on the environmental worldview of Kentucky residents. The study aimed to identify the determinants of disparity in the environmental worldview and the likely changes in the Kentucky residents' worldview between 1984 to 1988. The authors used variants of the NEP scale developed by Dunlap and Van Liere in 1978 as a dependent variable in their study. Findings of the study supported that younger educated males with higher income and living in urban areas were likely to hold a more environmental worldview. Furthermore, the results showed evidence of incremental changes in Kentucky residents' worldview toward a more environmental perspective within the entire population, between 1984 and 1988. Critical environmental experiences such as the 1988 drought and water restrictions were important factors that likely accelerated the change.

Arcury (1990) investigated the direct relationship between public environmental knowledge and environmental attitudes. He based his study on a statewide telephone survey of Kentucky residents in June, 1985. Four variants derived from the NEP scale were used as measures of environmental attitude: a base measure from the complete set of NEP item statements and three subscale measures based on four different item statements each. Three knowledge measures were considered. Consistent positive correlations were found between the four variants of the NEP scale and three environmental knowledge variables. Such result would suggest a knowledge-attitude association. The strong positive relationship between education and both knowledge about the environment and attitude toward the environment would emphasize knowledge leading over attitude. Thus, a relatively high level of public knowledge about environmental issues would affect the public awareness of the problem and direct its behavior toward a more environmentally friendly attitude.

Jones and Dunlap (1992) examined the changes in social bases of environmental concern over time. They tested the soundness of considering the hypotheses of a broadening base support for environmental protection and/or an economic contingency view in an environmental study. The broadening base hypothesis would suggest a spreading environmental concern downward into class structure. As a consequence, sociopolitical and socioeconomic variables would become weak determinants of environmental concern over time. The economic contingency hypothesis would support a decline in environmental concern in the case of worsening economic conditions. The disadvantaged socioeconomic groups would favor economic well-being over environmental quality. The analysis investigated the bivariate correlations as well as multiple regression relationships between the dependent variable “support for governmental spending on the environment” and the socio-political variables frequently suggested as predictors of environmental concern such as age, gender, race, income, political ideology, party affiliation, etc. Results provided little support for the broadening base support hypothesis and indicated no environmental concern spreading into class structure and across rural-urban dwellers. Indeed, sociopolitical variables remained significant predictors of environmental concern over the 1973-1990 period of study. Moreover, the study failed to corroborate the proposition that individual concern about environmental issues would be dependent on economic conditions.

This chapter has presented a review of relevant literature for the study. The next chapter will discuss the data and the theoretical framework.

CHAPTER 3

DATA AND METHODOLOGY

This chapter consists of five parts. A presentation of the mail survey along with a discussion of the data constitute the first section. The theoretical and analytical frameworks are discussed in sections two and three. The fourth section provides a narrative of the specific computation and different tests performed throughout the analysis. The different steps followed in the analysis are summarized at the end of the chapter.

3.1. Survey Design and Implementation

3.1.1. Mail Survey

In order to meet the objectives of the study, a statewide mail survey of the entire population of Louisiana dairy producers (428) was conducted in Summer, 2001. The survey was designed according to Dillman's method of surveying[1], which has been proven to yield a relatively high return rate. It included sending a first mail survey to each producer, a postcard reminder about two weeks later, and a second reminder two weeks after that to non-respondents. The third follow-up suggested by Dillman was not included because the required certified mail would not only be high cost, but also create a delivery problem associated with the requested recipient signature.

The first mailing included a cover letter stating the rationale for conducting the survey, with emphasis on the strict confidentiality of the individual responses; the twelve page questionnaire on the use of conservation practices and goals of Louisiana dairy producers; and a postage-paid return envelope. A postcard was sent two weeks later to remind dairy producers

[1] Further discussion can be viewed in Dillman (1978 and 1991).

about the importance of their responses. The third mailing included a new cover letter, the questionnaire and a return envelope. This mailing served as second reminder to non-respondents. Samples of the cover letter for each of the mailings and the postcard reminder are presented in Appendix B.

Because of the relatively small population of dairy farmers in Louisiana, it was highly important to receive a high return rate on the survey to ensure an acceptable scientific analysis. A payment of $10.00 was offered to producers who completed the survey and provided their name and social security number. Such payment has proven to be effective. Indeed, a similar payment was used in a previous study conducted by Fausti and Gillespie in 2000 to collect information on beef producer's risk attitudes, leading to a high return rate.

The mail survey for the study was conducted jointly with another study that focused on the goals of the Louisiana dairy producers. The reasons for the combined mail survey are three-fold. It was important to achieve a good rate of return on both surveys. Since both studies target the same population, sending two different surveys that include a significant number of similar questions would likely reduce the return rate of the second survey sent within a short period after the first survey. There would be a possibility that a survey on BMP adoption might not yield enough returns to perform a scientific analysis if the surveys were sent separately. Furthermore, Louisiana dairy producers had been subject to two previous mail surveys shortly before the survey was carried out. For these reasons, it was appropriate to prepare a single questionnaire that covered the interests of both studies. The questionnaire is presented in Appendix B.

The combined survey collected information on production characteristics such as size of operation, technology adoption, farm diversification and productivity; goals of dairy producers including conservation, profit maximization, expansion plans, risk management, and others; risk attitude and attitudes about social capital; producer and farm characteristics; knowledge and adoption of best management practices; and environmental attitude. The questionnaire was mailed out to the 428 private dairy producers identified as being in business in the first quarter of 2001. Dairy farms associated with research stations and universities were not included in the study. Five dairy farms were no longer in business by the time the survey was sent out. A total of 131 surveys were returned with 124 completed, yielding an effective rate of return of 29.31 percent.

3.1.2. Data Collected

3.1.2.1. Dairy Production Attributes

Thirteen questions were related to dairy production characteristics and covered a wide range of information. Producers were asked to state the number of cows in their dairy herd as well as the average pounds of milk per cow produced in 2000. Information on farmers' adoption of new technologies such as the computer, the PC DART program, bovine somatotropin (BSt) and artificial insemination was collected. These data served as proxies for producers' willingness to enhance production efficiency by adopting new technologies.

Diversification in farming activities is a strategy to minimize risk. Thus, dairy producers were asked which other livestock and crops they raised. Land ownership constitutes an important factor in agricultural production and may impact the decision to adopt conservation practices, especially those related to erosion and sedimentation management. Dairy farmer assessment of land owned compared to the total land included in the farm operation was collected. Number of family members and non-family employees working on the dairy operation may also offer an indication of the size of the operation, as well as labor available to conduct more labor intensive practices. Thus, this information was also collected.

3.1.2.2. Producer Risk Preferences and the Importance of Social Capital

Agricultural production is characterized by substantial risk and uncertainty. Decision making involves uncertainty regarding the probability of an expected result to occur. Researchers have developed a number of techniques to elicit producers' risk preferences such as the direct elicitation procedure (Fausti and Gillespie, 2000) and the interval approach discussed by King and Robison (1981).

In this study, the direct self-rank technique was used. Dairy producers' risk preferences were assessed based on the stated tendency to seek or avoid risk when making investment decisions. The question was asked as follows: "Relative to other investors, how would you characterize yourself?" Producers were asked to choose between the following responses: "I tend to take on substantial levels of risk in my investment decisions"; "I neither seek nor avoid risk in my investment decisions"; and "I tend to avoid risk when possible in my investment decisions." Producers who tended to take substantial levels of risk were considered as risk loving, those who preferred avoiding risk whenever it was possible were considered as risk averse, and those who neither sought nor avoided risk were considered as risk neutral.

Farmers were asked to evaluate the importance of their relationships with neighboring farmers and non-farmers, other dairy producers, lending institutions, agricultural businesses, and regulatory agencies. Each interaction was assessed as not important at all, not very important, somewhat important, or very important, and thus received a score of 0, 1, 2, or 3 respectively. For example, a relationship viewed as very important was assigned a score of 3. On the other hand, a relationship considered as not important at all received a score of 0.

3.1.2.3. Producers and Farm Characteristics

This section included eighteen questions that described the characteristics of dairy producers and the farm operation. The first part of the section collected information related to producers' socioeconomic backgrounds. Dairy producers were asked to specify their gender, marital status, ethnic background, age, level of educational attainment, the current generation operating the farm, and whether any family member planned to take over the dairy operation upon producer's retirement. Information on farm business structure, household net income, dairy operation current net worth and debt/asset ratio were solicited. Producers were asked to specify which of the following business structures applied to their dairy operation: sole proprietorship, partnership, family corporation or non-family corporation. Respondents were also asked to assess their household annual net income based on eight categories of income defined between the lower bound "less than $20,000" and an upper bound "greater than or equal to $140,000". An increment of $19,999 was added to specify the six categories between the two boundaries.

Dairy farm net worth was assessed using the following six categories: less than $50,000; $50,000 to $99,999; $100,000 to 199,999; $200,000 to 399,999; $400,000 to 799,999; and more than $800,000. Debt load is critical to producers' financial decision making. The debt-asset ratio gives insight as to the proportion of total debt compared to total farm asset value. Producers were asked to specify their debt-asset ratio among five categories: zero percent; 1 to 20 percent; 21 to 40 percent; 41 to 60 percent; and over 60 percent.

3.1.2.4. Best Management Practices

The section on best management practices included questions related to producers' awareness of regulations and programs dealing with water quality. Respondents were asked to identify their primary source of information about water quality problems and BMPs. Current implementation of each BMP was assessed by checking "yes" in the appropriate column of the BMP table. Four columns were included in the BMP table to account for the reasons for not implementing a BMP. These reasons included dairy producer's lack of information, need of more information, the high cost of implementation, and BMP not applicable to the respondent's farm. Producers were provided with a brief description of each BMP to assist in their assessment.

Questions related to geographical information that might impact dairy producers' adoption of a BMP were specified. The percentages of dairy farm land classified as "highly erodible" and as "well-drained" were assessed using five categories with 20 percent increments between each category for each classification. Dairy producers' awareness of a stream or river in the area was evaluated based on whether a stream and/or river ran through the farm, less than half a mile away from the farm, between one half and one mile away from the farm, or more than one mile away from the farm.

Frequency of meetings with LCES and NRCS agents, attendance at seminars and meetings that dealt with issues in the dairy industry, subscription to different farm magazines and dairy-related university publications are all potential means that would provide producers a better understanding of the dairy farming environment and therefore impact their decision making. Producers were asked to state the number of times they met with extension agents and NRCS personnel in 2000 and the number of subscriptions to farm magazines and dairy related publications.

3.1.2.5. Producer Environmental Attitude

Elicitation of dairy producers' attitudes toward the environment constituted the last section of the survey. Measurement of environmental attitude was based on the new environmental paradigm (NEP) revised scale developed by Dunlap *et al*. in 2000. The set of 15 items takes into account five features of an ecological worldview: the reality of limits to growth, the anti-anthropocentrism view, the fragility of nature's balance, rejection of exemptionalism, and the possibility of an ecocrisis (Dunlap *et al.,* 2000, p. 432).

Respondents were asked whether they strongly agreed, mildly agreed, were unsure, mildly disagreed or strongly disagreed with each stated item. Agreement with the eight odd-numbered items and disagreement with the seven even-numbered statements indicate pro-environmental responses. Therefore, respondents were assigned a score of 5 for "strongly agree", 4 for "mildly agree", 3 for "unsure", 2 for "mildly disagree", and 1 for "strongly disagree" for the odd-numbered statements, and a score in reverse order for the even-numbered assertions. A higher score would always connote a more pro-environmental attitude.

3.2. The Theory of Choice

Dairy producers' decisions to adopt one or a set of BMPs is a matter of choice that can be examined under the theoretical framework of **economics**, often called the science of choice (Parkin, 1997). Economics is a behavioral science. It is a social science as are sociology, political science, psychology, and philosophy.

Over the years, economists have provided different definitions of "economics" depending on what they intended to emphasize. Alfred Marshall's definition of economics in the early 1900s as "the study of humankind in the ordinary business of life" led to the neoclassical definition: "the study of choice in the ordinary business of life" (McCloskey, 1996). Henderson and Quandt (1980) presented it as "a social science which covers the actions of individuals and groups of individuals in the processes of producing, exchanging, and consuming goods and services." Case and Fair (1992) defined economics as "the study of how individuals and societies choose to use the scarce resources that nature and previous generations have provided." Miller (1994) viewed economics as "the study of how people make choices to satisfy their wants." Parkin (1997) simply described it as "the study of the choices people make to cope with scarcity."

Hence, economics is concerned with the allocation of scarce resources associated with the production, exchange and consumption of goods and services to achieve the most attractive end results and fulfill the human unlimited wants and needs. Rational choice theory constitutes a dominant paradigm in explaining human behavior and actions. Neoclassical economic theory and utilitarian theory form its basis.

3.2.1. Rational Choice Theory

Rational choice theory, usually referred to by economists as the economic approach or rational optimization approach, has been widely used in the social sciences. Like many theories, it uses abstract deductive reasoning by drawing conclusions and predictions from sets of assumptions, and provides guidance of "what ought to be", though the description of a situation is far from complete. Proponents of the rational choice approach claim that it provides a unified and rigorous framework to understand human behavior and actions, an analytical tool for relating aggregate events to micro-worlds of individual decision making, and has a great predictive power not found in other approaches (Friedman and Hechter, 1988; Rule, 1997; Chai, 2001).

On the other hand, critics have pointed to the shortcomings of the theory, including the unrealistic assumptions on preferences and the failure to incorporate such factors as altruism and cultural diversity. Such limitations, however, have confirmed the fact that a tractable representation of the complex world would only capture limited features of such complexity. Therefore, details are stripped away to expose only specific aspects of behavior relevant to the question being analyzed.

Rational choice theory assumes that individuals are purposive and intentional (Friedman and Hechter, 1988, p. 208). Individual decisions and actions are shaped by rational preferences (likes and dislikes) and constrained by resource scarcity, opportunity costs, institutional norms and quality of information.

3.2.1.1. Rational Preferences

The postulate of rationality of preferences constitutes a key assumption in the neoclassical economic analysis of behavior. Individuals are assumed to have explicit, complete, reflexive, and transitive rank ordered preferences over the possible outcomes of their actions. Preferences would also assume non-satiation, strict convexity, and continuity properties. In other words, individuals would consistently prefer "more of something to less" and "average outcomes to extremes".

Usually, preferences are described by means of the graphical representation of an indifference curve. Such a curve consists of a locus of pair-wise combinations of outcomes that would provide the same level of satisfaction to the decision maker. Each indifference curve represents a different level of utility. The continuity and completeness of a preference ranking would lead to a dense map of indifference curves. Curves positioned further to the north-east of the map are assumed to provide decision makers with higher satisfaction. In addition, the convexity of preferences ensures that the indifference curve exhibits the diminishing marginal rate of substitution. In other words, the more an individual has of a good, the less satisfaction he perceives from an additional unit of the same good and the more he is willing to exchange it for a given amount of the other good (Case and Fair, 1992; Varian, 1993; Parkin, 1997).

3.2.1.2. Optimization Behavior

The fundamental economic problem has been attributed to the limited resources available to satisfy human beings' unlimited wants and needs (Parkin, 1997). Resource scarcity drives individuals to make choices to attain satisfactory ends consistent with their preference hierarchy. Differential access to resources affects the individual's ability to attain the alternative end results, making some easy to achieve, and others more difficult or even impossible to reach (Friedman and Hechter, 1988). However, decision makers are assumed to conduct rational calculation and subsequently select the course of action likely to be associated with the highest outcome values.

Utility theory provides an understanding of individuals' choice through **utility maximization** behavior (Varian, 1993; Parkin, 1997). Individuals' preferences are associated with a real-value indexed utility. Consequently, individuals' choice is assumed to favor the course of action that provides the highest utility, or maximum satisfaction. Yet, individuals' choices often fail to agree with such an ideal proposition.

There are other factors that affect individuals' decisions. One factor is what economists term as **opportunity costs**, which arise with making a specific choice. These implicit costs are associated with the act of foregoing the next best alternative available to decision makers. Individuals must consider these implicit costs in their pursuit of maximum benefits and satisfaction. High opportunity costs can affect the attractiveness of the most preferred action and may urge decision makers to act accordingly, by choosing a lower level of satisfaction attainment instead. Thus, individuals' choices favor the course of action that would provide the highest expected net benefits.

Likewise, institutional norms and rules, as well as access to better quality information at the time a choice has to be made, also influence individuals' decision outcomes. Perception of rewards and costs are shaped by social institution rules. As Friedman and Hechter expressed: "…an individual will find his or her actions checked from birth to death by familial and school rules; laws and ordinances; firm policies; churches, synagogues and mosques; and hospitals and funeral parlors" (Friedman and Hechter, 1988, p. 202).

The role of information in determining a situation as involving certainty or risk has been emphasized in most microeconomics textbooks as well as risk analysis and choice behavior studies (Heath, 1976; Williams and Findlay, 1981; Machina, 1987; Varian, 1992; Keeney and Raiffa, 1993; Lichtenberg, 2000; Chai, 2001). Under certainty, individuals are assumed to possess all the information necessary for making selections among alternative strategies. The decision maker can make a clear choice between the available course of action, and select the most preferred alternative. In a risky situation, individuals face many possible effects of each alternative choice of action. In consequence, decisions are strategically made according to the likelihood of occurrence of each end result. Individuals may also reduce the uncertainty surrounding their choices by acquiring more information.

3.2.2. Discrete Choice Modeling

Discrete choice models are econometric modeling techniques that focus on the analysis of the behavior of decision makers who face a finite set of alternative choices. Such models attempt to relate the conditional probability of a particular choice to various attributes of the alternatives, which are specific to each individual, as well as the characteristics of the decision makers (Judge *et al.*, 1985). The choice behavior of individuals with only two alternatives can be examined using a dichotomous dependent variable as in the case of binary choice models.

There are different ways to approach such models. Models relying on the linear random utility assumption are based on an individual decision maker maximizing his/her expected utility derived from the choice. The linear random utility assumption is expressed in equation (3.1).

$$(3.1) \qquad \begin{cases} U_{i0} = \overline{U}_{i0} + e_{i0} = z_{i0}'\delta + w_{i0}'\gamma_0 + e_{i0} \\ U_{i1} = \overline{U}_{i1} + e_{i1} = z_{i1}'\delta + w_{i1}'\gamma_1 + e_{i1} \end{cases}$$

where $\overline{U}_{ij}$ = average utility perceived by individual i from choosing alternative j; e_{ij} = random disturbances associated with individual i's choice of alternative j; z_{ij} = vectors of attributes associated with alternative j and specific to individual i; and w_i = socio-economic characteristics specific to individual i.

The probability that one alternative is chosen versus the other is then linked to the probability distribution of the error differences in the utilities from the choices. The expression of the probability that individual i would choose alternative A (y_i =1) versus alternative B (y_i = 0) is given in equation (3.2).

$$(3.2) \qquad p_i = prob\left(y_i = 1 \mid x\right) = prob\left(y_i^* > 0\right) = prob\left(e_i^* > -x_i'\beta \right) = F(\beta' X)$$

where $y_i^* = U_{i1} - U_{i0}$ (the latent variable) $= (z_{i1} - z_{i0})'\delta + w_i'(\gamma_1 - \gamma_0) + (e_{i1} - e_{i0}) =$
$\left[(z_{i1} - z_{i0})', w_i'\right]\begin{bmatrix} \delta \\ \gamma_1 - \gamma_0 \end{bmatrix} + e_i^* = x_i'\beta + e_i^*$; and F = cumulative distribution function of e_i^* evaluated at $x_i'\beta$.

The latent variable y_i^* is unobservable. However, it can be linked to the observed binary variable y_i using the relation in equation (3.3).

$$(3.3) \qquad y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \leq 0 \end{cases}$$

The interpretation of the relationship between a specific explanatory variable and the outcome of the probability is different from the standard interpretation in multiple linear regression. Indeed, in the multiple linear regression case, the parameter estimate accounts for the changes in the dependent variable with respect to a change in the exogenous variable. Therefore, a significant parameter would imply a significant effect on the dependent variable. The nonlinearity in the binary response model, however, prevents such interpretation and requires a different measure to summarize the effect of an explanatory variable. The partial change in the probability of an event is called a **marginal effect**. It is obtained by taking the partial derivative of the expression of the probability with respect to a change in the variable of interest.

Assumption of a specific form for the distribution of the error terms allows for computing the probability of $Y = 1$, given the explanatory variables $\boldsymbol{X}$. The standard normal and logistic distributions represent the two distributions frequently considered in discrete choice modeling. Both distributions are symmetric and lead to probabilities confined to the unit interval.

3.3. Analytical Framework

The present study aims to analyze the likelihood of a dairy producer of a specific description to adopt one or more technologies. The conduct of a probit analysis will allow for estimating the probability of a dairy producer adopting a specific BMP, given the economic and non-economic factors hypothesized as determinant in the decision to adopt and the assumption of normal random errors associated with the random utility. Analysis of the coefficients and marginal effects of significant explanatory variables establishes the relationship between the explanatory variables and the conservation practices.

Findings of previous studies suggest the appropriateness of assuming contemporaneous correlation between adoption equations of multiple management measures. Consequently, multivariate probit analysis is also conducted to determine the types of producers that adopt two or more practices. The conduct of univariate, bivariate and multivariate probit analyses along with principal component analysis constitute the main steps in the econometric modeling.

3.3.1. Econometric Models

3.3.1.1. Probit Model

The probit model constitutes one of the two basic binary choice models commonly used to analyze the choice behavior of an individual facing two alternatives and opting for one. The description of the model follows the theoretical presentation of discrete choice modeling in the previous section, with the specification that the random utility function is associated with a normally distributed error term.[2] Thus, the probability p_i of choosing alternative A versus alternative B can be expressed as in equation (3.4), where Φ represents the cumulative distribution of a standard normal random variable.

(3.4) $$p_i = \text{prob}[Y_i = 1 \mid X] = \int_{-\infty}^{x_i'\beta} (2\pi)^{-1/2} \exp\left(-\frac{t^2}{2}\right) dt = \Phi(x_i'\beta)$$

The relationship between a specific variable and the outcome of the probability are interpreted by means of marginal effect which account for the partial change in the probability of an event. The marginal effect associated with a continuous explanatory variable x_k on the probability $P(y_i = 1 \mid X)$, holding the other variables constant, can be derived as follows:

(3.5) $$\frac{\partial p_i}{\partial x_{ik}} = \phi(x_i'\beta)\beta_k$$

where ϕ represents the probability density function of a standard normal random variable. The sign of the marginal effect depends on the sign of the coefficient β_k and its magnitude is

[2] The logit model constitutes the second model commonly used to analyze binary choice. The error terms in this model are assumed to yield a logistic distribution.

determined by the values of both β_k and $X\beta$. Consequently, the size of the effect depends on the levels of all variables included in the X matrix. Different estimates of marginal effects can be obtained from different values of the independent variables.

Estimates of marginal effects at the mean values of all independent variables constitute the commonly reported summary measure in many studies. Such results are automatically obtained using LIMDEP. However, they might be inappropriate if the X matrix includes dummy variables. The mean value for a dummy variable is not suitable because it does not correspond to any observable values (Long, 1997). Hence, it would be more appropriate to estimate the marginal effects at specific values of the dummy variable while holding continuous variables at their means. In this study, the value of a specific dummy variable included in the marginal effect estimation was set to either 0 or 1 based on its mean value. Dummy variables with mean values less than 0.5 were set to 0 and 1 otherwise.

Furthermore, discrete changes in the predicted probabilities constitute an alternative to the marginal effect when evaluating the influence of a dummy variable d. Such effect can be derived from equation (3.6).

$$\Delta = \Phi\left(\overline{X}\beta,\ d=1\right) - \Phi\left(\overline{X}\beta,\ \mathrm{d}=0\right) \tag{3.6}$$

In this analysis, three types of marginal effects were computed: at the mean values of all variables; at specific values of the dummy variables; and assuming discrete changes for significant dummy variables. The significance of a marginal effect was assessed using the delta method as presented in the section, Special Computations and Tests.

3.3.1.2. Bivariate Probit Model

Discrete modeling that requires the inclusion of two equations with correlated disturbances extends the probit model to what is known as the bivariate probit model. The basic assumption of normally distributed error terms in each equation still holds. The assumption of contemporaneous correlation necessitates the consideration of the two equations simultaneously. The specification for the two-equation model is presented in equation (3.7):

(3.7) $$\begin{cases} y_1^* = \beta_1' x_1 + e_1 \quad , \quad Y_1 = 1 \text{ if } y_1^* > 0, \text{ and 0 otherwise} \\ y_2^* = \beta_2' x_2 + e_2 \quad , \quad Y_2 = 1 \text{ if } y_2^* > 0, \text{ and 0 otherwise} \end{cases}$$

where $E[e_1] = E[e_2] = 0,\ \text{var}(e_1) = \text{var}(e_2) = 1,\ \text{cov}[e_1, e_2] = \rho$ and e_i accounts for the standard normal error term associated with equation i. The cumulative density function (cdf) associated with the bivariate normal variables is noted as $\Phi_2(.)$ and expressed in the following equation:

(3.8) $$\Phi_2(Z_1, Z_2, \rho) = \int_{-\infty}^{x_{i1}\beta_1} \int_{-\infty}^{x_{i2}\beta_2} \phi_2(z_1, z_2, \rho)\, dz_1\, dz_2$$

where: $\phi_2(z_1, z_2, \rho) = \dfrac{e^{-(1/2)\,(z_1^2 + z_2^2 - 2\rho\, z_1 z_2)/(1-\rho^2)}}{2\pi\left(1-\rho^2\right)^{1/2}}$ represents the probability density function associated with the bivariate standard normal variables. The subscript 2 in the probability density ϕ_2 and cumulative density Φ_2 indicates the bivariate nature of the distribution. The construct of the log likelihood requires the following change variable (Greene, 2000):

(3.9)

- $q_{i1} = 2y_{i1} - 1$ and $q_{i2} = 2y_{i2} - 1$; thus $q_{ij} = \begin{cases} 1 \text{ if } y_{ij} = 1 \\ \text{-1 if } y_{ij} = 0 \end{cases}$ for $\begin{cases} i = 1, \ldots, N \\ j = 1,2 \end{cases}$
- $z_{ij} = \beta_j' x_{ij}$ and $w_{ij} = q_{ij} z_{ij}$, for $j = 1,2$.
- $\rho_{i*} = q_{i1} q_{i2}\, \rho$

where y_{ij} represents the observed value for individual i in equation j, z_{ij} the index function and ρ the correlation coefficient between the two equations. The probabilities that enter the likelihood function become:

(3.10) $$\text{prob}(Y_{i1} = y_{i1}, Y_{i2} = y_{i2}) = \Phi_2(w_{i1}, w_{i2}, \rho_{i*})$$

Marginal effects associated with the bivariate probit model are computed as follows:

(3.11) $$\frac{\partial E[Y_1 \mid Y_2 = 1, X]}{\partial X} = \frac{\partial[\text{prob}(Y_1 = 1 \mid Y_2 = 1, X]}{\partial X} = \frac{\partial}{\partial X}\left[\frac{\Phi_2(\gamma_1 ' X, \gamma_2 ' X, \rho)}{\Phi(\gamma_2 ' X)}\right]$$

where γ_i contains all the nonzero elements of β_i and possibly some zeros in the positions of variables appearing in only one of the equations. Marginal effect results may be obtained using LIMDEP.

3.3.1.3. Multivariate Probit Model

A more general extension of the probit model involves the inclusion of more than two equations with correlated disturbances in the model as in the seemingly unrelated regression (SURE) model (Greene, 2000). The multivariate model would extend to more than two outcome variables by simply adding more equations. The general formulation would be as expressed in equation (3.12) where the error terms $e_1, e_2, \ldots, e_M$ have a multivariate normal distribution with mean vector 0 and covariance matrix Σ with diagonal elements equal to 1.

(3.12) $$\begin{cases} y_1^* = \beta_1 ' X_1 + e_1, \quad y_1 = 1 \text{ if } y_1^* > 0, \text{ and 0 otherwise} \\ y_2^* = \beta_2 ' X_2 + e_2, \quad y_2 = 1 \text{ if } y_2^* > 0, \text{ and 0 otherwise} \\ . \\ . \\ . \\ y_M^* = \beta_M X_M + e_M, \quad y_M = 1 \text{ if } y_M^* > 0, \text{ and 0 otherwise} \end{cases}$$

The probabilities that enter the likelihood function would become:

(3.13) $$\text{prob}(Y_{i1}, Y_{i2}, \ldots, Y_{im} / x_{i1}, x_{i2}, \ldots, x_{im}) = \text{MVN}(TZ, TRT`)$$

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

These extended models involve more complex computation than the simple probit model. The evaluation of higher-order multivariate normal integrals has raised a practical obstacle (Greene, 2000). Recent research has promoted improved methods to solve the multidimensional probability integrals in the likelihood function and conditional moment conditions (Pakes and Pollard, 1989; Geweke, 1989; Stern, 1992; Börsch-Supan and Hajivassiliou, 1993; and Keane, 1994).

The marginal effects for the continuous explanatory variables were derived by taking the derivative of the expected value of Y_1 given that all other Y's are equal to 1, with respect to the regressors in the model. The matrix computation of the marginal effects associated with the multivariate probit model is presented in equation (3.14).

$$\frac{\partial E_1}{\partial X} = \frac{\partial\{(\text{prob}(Y_1=1,Y_2=1,\ldots,Y_M=1)\,|\text{prob}(Y_2=1,\ldots,Y_M=1)\}}{\partial X}$$

$$(3.14) \qquad = \sum_{m=1}^{M}\left\{\left[\frac{\partial\,\text{prob}(Y_1=1,Y_2=1,\ldots Y_M=1)}{\partial Z_m}\right]c_m * \frac{1}{\text{prob}(Y_2=1,\ldots,Y_M=1)}\right\}$$

$$- E_1 * \sum_{m=2}^{M}\left\{\left[\frac{\partial\,\text{prob}((Y_2=1,\ldots,Y_M=1)}{\partial z_{(m)}}\right]c(m) * \frac{1}{\text{prob}(Y_2=1,\ldots,Y_M=1)}\right\}$$

where $E_1 = \frac{\text{prob}(Y_1=1,Y_2=1,\ldots,Y_M=1)}{\text{prob}(Y_2=1,\ldots,Y_M=1)}$, X = all regressors in the model, and $z_m = X`c_m = \beta_m`x_m$.

Problems Encountered with the Marginal Effects Computation. The marginal effect results obtained for the multivariate probit model from LIMDEP programs showed similar values xup to the fourth digit number. Therefore, different procedures were used to overcome the problem.

This first procedure aimed to achieve similar goals as the LIMDEP procedure: to determine the marginal effect of a specific variable on the conditional probability of adopting a single management practice given that the other considered practices were also adopted. It proposed to link a specific latent variable to the conditional probability involved in the computation of the marginal effects. It consisted of two parts: first, to obtain a conditional distribution from a multivariate normal distribution; and then to associate such distribution with the conditional probability in the marginal effects computation. The case of three variables is described below.

Assume Y^* is a vector of three random variables y_1^*, y_2^* and y_3^*, where each y_i^* is normally distributed. Y^* would then yield a multivariate normal distribution:

(3.15) $$Y^* = \begin{bmatrix} y_1^* \\ y_2^* \\ y_3^* \end{bmatrix} \rightarrow MVN[\mu, \Sigma] \qquad \text{where } \mu = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix}, \quad \Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix}$$

where MVN stands for multivariate normal distribution, μ_i the mean of random variable y_i^*, and σ_{ij} the covariance between y_i^* and y_j^*. Random variable ($y_1^* \mid y_2^* = a$, $y_3^* = b$) would be normally distributed. Its distribution may be specified as:

(3.16) $$(y_1^* \mid y_2^* = a, y_3^* = b) \rightarrow N(\mu_{y1|y2,y3}, \Sigma_{y1|y2,y3})$$

where $$\mu_{y1|y2,y3} = \mu_1 + \Sigma_{12}\Sigma_{22}^{-1}\begin{bmatrix} -\mu_2 \\ -\mu_3 \end{bmatrix}, \qquad \Sigma_{y1|y2,y3} = \Sigma_{11} - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21} = \sigma^2_{y1|y2,y3}$$

$$\Sigma_{12} = [\sigma_{12} \ \ \sigma_{13}], \quad \Sigma_{22} = \begin{bmatrix} \sigma_{22} & \sigma_{23} \\ \sigma_{32} & \sigma_{33} \end{bmatrix}, \text{ and } \Sigma_{21} = \begin{bmatrix} \sigma_{21} \\ \sigma_{31} \end{bmatrix}$$

Assume Y is a vector of three binary variables y_1, y_2 and y_3 that characterize a multivariate probit model. The system of three equations is as follows:

(3.17) $$\begin{cases} y_1^* = \beta_1' x_1 + \varepsilon_1, & y_1 = 1 \text{ if } y_1^* > 0, \text{ and 0 otherwise} \\ y_2^* = \beta_2' x_2 + \varepsilon_2, & y_2 = 1 \text{ if } y_2^* > 0, \text{ and 0 otherwise} \\ y_3^* = \beta_3' x_3 + \varepsilon_3, & y_3 = 1 \text{ if } y_3^* > 0, \text{ and 0 otherwise} \end{cases}$$

It follows that the random variable Y^* described above can be identified as the latent variable associated with the multivariable probit model. If one can assume that the conditional probability involved in the computation of the marginal effects is associated with random variable ($y_1^* | y_2^*, y_3^*$), then the conditional marginal effects can be estimated as in the simple probit model because the conditional variable ($y_1^* | y_2^*, y_3^*$) is normally distributed. Scaling with the standard error will lead to a standard normal random variable.

$$(3.18) \qquad (y_1 | y_2 = 1, y_3 = 1) = \begin{cases} 1 & \text{if } \dfrac{1}{\sigma}(x_1\beta_1 - \delta_1 x_2 \beta_2 - \delta_2 x_3 \beta_3) + e > 0 \ , \qquad e \to N(0,1) \\ 0 & \textit{otherwise} \end{cases}$$

where $\mu_i = x_i\beta_i$, $\mu_{y1|y2,y3} = x_1\beta_1 - \delta_1 x_2 \beta_2 - \delta_2 x_3 \beta_3$, and $\sigma = [\Sigma_{y1|y2,y3}]^{1/2} = (\sigma^2_{y1|y2,y3})^{1/2}$

The probability density function (pdf) and cumulative distribution function (cdf) would be:

$$(3.19) \qquad \begin{aligned} f(y_1 | y_2 = 1, y_3 = 1) &= \phi\left[\frac{1}{\sigma}(x_1\beta_1 - \delta_1 x_2 \beta_2 - \delta_2 x_3 \beta_3)\right] \\ P(y_1 | y_2 = 1, y_3 = 1) &= \Phi\left[\frac{1}{\sigma}(x_1\beta_1 - \delta_1 x_2 \beta_2 - \delta_2 x_3 \beta_3)\right] \end{aligned}$$

The apparent simplicity in the procedure presented, however, a flaw. The reasoning failed to take into account the inequality requirement in the assumption of the conditional probability. $P(y_1 | y_2 = 1 \text{ and } y_3 = 1)$ can be expressed as $P(y_1 | y_2^* > 0 \text{ and } y_3^* > 0)$. The inequality requirement would necessitate the use of a truncated multivariate distribution.

The second procedure was based on the need for a truncated distribution as mentioned earlier. Previous studies used the truncated bivariate normal density (Saha *et al.*, 1994; Van der Laan, 1996; Ghrler, 1997; Ghrler and Prewitt, 2000). The expectation of a truncated bivariate normal density can be described as follows: Let us assume two random normal variables y_1 and y_2 that yield a bivariate normal distribution specified as:

(3.20) $\left(y_1, y_2\right) \rightarrow \Phi_2(\mu_1, \mu_2, \sigma_1, \sigma_2, \rho)$

where μ_i and σ_i represent the mean and variance of variable $\mathbf{y_i}$ and ρ the covariance between y_1 and y_2. The conditional expectation of y_1 given that $y_2 > a$ would be:

(3.21) $$E[y_1 \mid y_2 > a] = \mu_1 + \rho\sigma_1 * \lambda(\alpha_2) \quad , \alpha_2 = \frac{a - \mu_2}{\sigma_{y2}} \text{ and } \lambda(\alpha_2) = \frac{\phi(\alpha_2)}{1 - \Phi(\alpha_2)}$$

where $\phi(.)$ and $\Phi(.)$ account for the pdf and cdf of a normal distribution, and $\lambda(\alpha)$ the Mills ratio. In the context of the bivariate probit model, the following conditional probability is derived:

(3.22) $$\text{prob}\left(y_1 = 1 \mid y_2 = 1\right) = \Phi(X_1\beta_1) + \rho\lambda(\alpha).$$

The marginal effect of a specific explanatory variable x_k on the conditional probability would then be as expressed in equation (3.23).

(3.23) $$\frac{\partial \text{prob}(y_1 = 1 \mid y_2 = 1)}{\partial x_k} = \phi(X_1\beta_1)\beta_1 + \rho\beta_2(\lambda\alpha - \lambda^2)$$

where X_i and β_i represent the matrix of all independent variables x_{ik} and the parameters associated with latent variable y_i^* in each probit model. The extension of such specification to a case that involves more than two normal random variables could be a solution to the marginal effect problem associated with the multivariate probit estimation.

The third procedure investigated discrete changes in the predicted probabilities of adopting all management practices under consideration the model. Such a measure could be conducted as an alternative to marginal effects. One should, however, bear in mind that marginal effect and discrete change measures are not equal. Indeed, the marginal effect accounts for the slope of the probability curve at x_k=a, whereas a discrete change represents the slope of a line that connects the probability values at $x_k = a$ and $x_k = a + \Delta$. Nevertheless, the two measures may be close in the nearly linear portion of the probability curve. Discrete changes in the predicted probability of adopting all practices at the same time, given a change in a specific independent variable, and holding all other variables constant were assessed using equation (3.24).

$$\frac{\Delta prob(Y_1,\ldots,Y_m \mid X)}{\Delta x_k} = prob(Y_1,\ldots,Y_m \mid X, x_k + \delta) - prob(Y_1,\ldots,Y_m \mid X, x_k) \tag{3.24}$$

where δ is the increment in the value of variable of interest $\mathbf{x}_k$. Discrete changes in the probabilities were estimated for variables that yielded statistically significant coefficients for β.

3.3.2. Variables Included in the Model

3.3.2.1. The Binary Dependent Variables

Each management practice included in the set of BMPs for the Louisiana dairy industry was assumed to define one equation in each probit model and the subsequent analysis. Producers' responses as to whether or not they adopted a BMP constituted the binary dependent variable. All 21 BMPs were considered in this study. There were a relatively high percentage of respondents suggesting the non applicability of some BMPs to their farms. Inquiries with Donny Latiolais, an NRCS agent responsible of the southeast Louisiana region, provided a better understanding of each BMP and producer responses. The reasons for producers responding "non applicable to my farm" could be two-fold: the management practice is indeed not applicable to the farm because of the site specific characteristic of BMPs; or the possibility that producers are implementing some type of practice similar to the one asked but fail to recognize the specific BMP despite the glossary provided in the survey. In such a case, the BMP is applicable to the respondent farm operation. Given the available information, it was impossible to sort out the stated "non applicability" responses according to these two reasons. Thus, producers answering "BMP Not Applicable to My Farm" was treated as not adopting the BMP.

The 21 management practices were grouped into four main categories for the purpose of multivariate probit analysis, based on the primary objective of each management practice. Eleven practices aimed to control erosion and sediment. Five practices focused on the management of facility wastewater and runoff. Nutrient and pesticide management formed a separate group. Three management practices were related to grazing management. A summary of these variables is presented in Table 3.1. The producer's response regarding his current adoption of each management practice defined the binary dependent variable that took the value of one if the BMP was currently implemented and zero otherwise. The unobservable latent variable y^* associated with each binary variable was assumed to be a linear function of the hypothesized independent variables described in the next section.

3.3.2.2. The Explanatory Variables Included in the Analysis

A number of factors were hypothesized to affect the probability of adopting a specific management practice. Such factors included farm attributes, dairy producer characteristics, institutional variables and dairy producer's attitude toward risk and the environment. Thirty-two independent variables displayed in Table 3.2 were included as determinant of dairy farmers' decision making with regard to the implementation of conservation practices.

3.3.2.2.1. Farm Attributes

Larger sized farms have generally been associated with an increased likelihood to adopt technology (Westra and Olson, 1997; El-Osta and Morehart, 1999; Davis and Gillespie, 2000). Adoption of a new technology often involves high initial outlay and farmers with greater resources are better able to afford the technology. As Feder *et al.* (1985) stated, "the theoretical

Table 3.1. Binary Dependent Variables in the Analyses.

Categories	Management Practices
Erosion and Sediment Control Practices	
	1. Conservation Tillage Practices
	2. Cover and Green Manure Crop
	3. Critical Area Planting
	4. Field Borders
	5. Filter Strips
	6. Grassed Waterways
	7. Heavy Use Area Protection
	8. Regulating Water in Drainage System
	9. Riparian Forest Buffer
	10. Sediment Basin
	11. Streambank and Shoreline Protection
Facility Wastewater and Runoff Management	
	1. Roof Runoff Mangement
	2. Waste Management System
	3. Waste Storage Facility
	4. Waste Treatment Lagoon
	5. Waste Utilitzation
Nutrient and Pesticide Management	
	1. Nutrient Management
	2. Pest Management
Grazing Management	
	1. Fence
	2. Prescribed Grazing
	3. Trough or Tank

Table 3.2. Explanatory Variables Included in the Analyses.

	Variables	Definition
Farm Characteristics		
1	COWS	Number of cows in the dairy herd.
2	YIELD	Average pounds of milk produced per cow in 2000.
3	PASTU	Dummy for pasture-based operation.
4	OCROP	Diversification of farming activities (other livestock and crops).
5	LAND	Proportion of land owned over total acres operated.
6	PART	Part-time employees.
7	FULT	Full-time employees.
8	BSTR	Dummy for business structure of the dairy farm (1 for corporation).
9	NWTH	Dummy for dairy operation current net worth. (1 for net worth >= $400,000).
10	DEBT	Debt-Asset ratio (increments of 20%).
11	HEL	Percent of land classified as highly erodible (increments of 20%).
12	WDL	Percent of land classified as well-drained (increments of 20%).
13	STRM1	Dummy for stream or river running through the farm.
14	STRM2	Dummy for nearest stream or river more than a mile from the dairy farm.
Operator Characteristics		
1	AGE	Age of respondent.
2	EDUC	Dummy for level of education. (1 if college degree).
3	OFFF	Dummy for off-farm job.
4	TOVR	Dummy for whether any family plans to take over the operation.
5	CSP	Dummy for farmer's participation in any dairy cost-sharing program.
6	EXP	Number of years dairy farmer has been operating the farm.
Institutional Variables		
1	COOP	Dummy for being a member of a milk cooperative.
2	DHIA	Dummy for being a member of the Dairy Herd Improvement Association.
3	LCES	Number of times farmer met with LCES agents in 2000.
4	NRCSP	Dummy for farmer having developed or updated a dairy farm plan with NRCS.
5	SEM	Number of seminars/meetings on dairy industry issues attended in 2000.
Attitudinal Variables		
1	RISK	Dummy for risk averse dairy farmer. (1 if dairy farmer is risk averse).
2	SCAP1	Relationship with neighboring farmer.
3	SCAP2	Relationship with lending institutions.
4	SCAP3	Relationship with other agricultural businesses.
5	SCAP4	Relationship with non farmer neighbors.
6	SCAP5	Relationship with regulatory agencies.
7	ENV	Farmer attitude toward the environment (NEP score).

literature suggests that large fixed costs cause a reduced tendency to adopt and a slower rate of adoption on smaller farms." Furthermore, even size neutral technologies may be more heavily adopted by larger farmers if the costs associated with learning are appropriated as fixed expenses (Feder *et al.*, 1985). Total number of cows in the dairy herd (COWS) was used as a proxy for farm size in this study. Larger dairy farms were hypothesized to be more involved in wastewater and runoff management to better handle the large amount of manure and waste produced on their farms.

Farm productivity may reflect producers' openness to new technology that provides greater productivity gains (Ghosh *et al.*, 1994; Zepeda, 1994; El-Osta and Morehart, 1999). It characterizes farm operator management ability. Farm productivity has usually been incorporated in technological adoption studies as an endogenous variable because technology affects productivity. El-Osta and Morehart (1999) considered YIELD as a determinant factor in the adoption of advanced milking parlors and DHIA technology in the U.S. dairy industry, and used an instrument variable for yield to deal with the endogeneity problem. Zepeda (1994) included dairy farm productivity as one of the three endogenous variables in the simultaneous equations of adopting DHIA. In this study, cow productivity was not considered as an endogenous variable because conservation management practices target primarily the enhancement of the environment, not farm production. Therefore, the productivity variable was included as an exogenous determinant of BMP adoption. Average pounds of milk per cow (YIELD) was incorporated as an explanatory variable to account for the differential ability of the productive farm to bear the fixed adoption costs of conservation management as high productivity would likely ensure larger profits.

Diversification in farming activities is a risk management strategy, one of the common tools for managing agricultural risks associated with yield, price and income (Fleisher, 1990; Anderson and Dillon, 1992). Hence, risk aversion would drive farmers to engage in alternative enterprises. Fernandez-Cornejo *et al.* (1994) included output diversification as one proxy of risk aversion in their study of the adoption of integrated pest management techniques by vegetable growers in Florida, Michigan and Texas. They found a significant positive relationship between the diversification variable and farmers' adoption of the technique. In this study, producers engaged in diverse agricultural enterprises were hypothesized to likely adopt management practices relevant to each type of activity. Variable (OCROP) was included to account for the number of other farming activities in which the dairy farmer was involved besides milk production and raising hay. It was hypothesized to be positively correlated with the probability to adopt a BMP.

The effect of land tenure has been examined in many technology adoption studies. Soule *et al.* (2000) emphasized the importance of land tenure in farmer's adoption of conservation practices and the negative association between adoption and variable "renter" of land. Cardona (1999) also pointed out sugarcane farmers' unwillingness to implement BMPs on rented land, showing a negative relationship between adoption and the variable "tenure". Fernandez-Cornejo *et al.* (1994) provided a discussion on the likelihood of land ownership to influence adoption of innovations requiring investments tied to the land. Tenants' lack of motivation to adopt would be due to the perception of benefits accruing to the landowner, and not to the renter. In this study, the proportion of owned land to total acres operated (LAND) was included. A greater fraction of land owned was hypothesized to increase the adoption of soil management practices.

Respondents were asked whether their operation was a pasture-based operation or a free-stall operation. In pasture-based operations, cows are allowed to graze much of the day on forages. A free-stall operation differs from the pasture-based operation in that it includes separate areas for milking, feeding and lounging, all generally inside the structure on cement. Animals are not allowed to graze on forage. Both pasture-based and free-stall dairy farms were expected to be involved in the runoff and waste management practices. Dairy farms more involved in grazing activity were assumed to have information about grazing management practices. Pasture-based operation was included as dummy variable (PASTU) that took the value of one if the operation was forage based and zero otherwise. It was hypothesized to enhance the adoption of grazing management practices.

As discussed by Feder *et al.* (1985), labor availability may affect a farmer's decision to adopt technology. Labor shortages promote the adoption of labor-saving practices, but hinder the implementation of technologies that require more labor input. The number of part-time (PART) and full time (FULT) employees were included as explanatory variables. A greater labor force was hypothesized to increase the adoption of labor demanding conservation practices such as waste management, nutrient management and pesticide management. On the other hand, some labor saving practices might include conservation tillage.

Business structure constitutes a decision factor that is likely to impact the adoption of management practices. The corporate farm structure allows producers to take greater investment risk than sole proprietors. Furthermore, sole proprietors are likely older farm operators with shorter planning horizons, and therefore, less willing to adopt technology (El-Osta and Morehart, 1999, p. 88). Business structured as a farm corporation was included as a dummy variable

(BSTR) which took the value of one for a corporate farm and zero otherwise. BSTR was hypothesized to increase the adoption of BMPs.

A dairy farmer's financial situation could also impact his decision as to whether to incur greater costs by implementing management practices. Dairy operations with greater net worth are farms with greater resources, able to afford the costs of implementing a BMP. Current dairy operation net worth (NWTH) was included as a dummy variable that took the value of one if the farm net worth was at least $400,000, which described the level of net worth of a medium sized dairy farm.

Debt-asset ratio (DEBT) is critical in a dairy farmer's financial decision making. Higher debt that is most likely borne by turnkey and established dairy farms may indicate two different things. The debt could be the result of an increased investment from a recent adoption of technology. In such a case, the debt variable would positively affect the adoption of BMPs. On the other hand, a high debt load could be an impediment to new BMP implementation because the farm operator would be reluctant to increase his or her liabilities. Thus, a high debt-asset ratio would be less likely to increase adoption. The ambiguous effects of debt-to-asset ratio on adoption were discussed by Fernandez-Cornejo *et al.* (1994). They found higher debt/asset ratios associated with an increased adoption of integrated pest management by vegetable growers in Florida and Texas, and a negative effect on growers in Michigan. Gould *et al.* (1989) found a negative association of debt ratio and adoption of conservation tillage in Wisconsin. In this study, the sign of variable DEBT is to be explored.

The four remaining farm attribute variables relate to the physical characteristics of the farmer's land. Operators with land classified as highly erodible would have a greater need to carry out soil conservation practices. Thus, variable HEL, which accounts for the percentage of the farmer's land classified as highly erodible, was included to capture this effect. The drainage characteristics of the land is important in farming activities. The drainage variable would affect some BMP adoption more than others. Dairy farmers who have poorly drained areas may opt to improve their drainage system through water control structures. Variable WDL measured the percentage of the farmer's land classified as well-drained. WDL was hypothesized to specifically increase the implementation of erosion and sediment control practices.

Two dummy variables were included to account for the existence of a stream and/or river on the dairy farm or nearby. Variable STRM1 took the value of one if a stream and/or river ran through the farm. Variable STRM2 took into consideration the existence of the nearest stream or river distant from the farm, taking the value of one if the nearest stream or river was more than one mile away from the dairy farm and zero otherwise. STRM1 variable was expected to increase the implementation of BMPs, especially those such as streambank and shoreline protection, whereas STRM2 would likely reduce the adoption of BMPs.

3.3.2.2.2. Dairy Operator Characteristics

Six variables that describe dairy operators in Louisiana were considered in the econometric model. The roles of age and educational attainment in farmers' decisions to adopt technology have been shown in previous studies (Feder *et al.*, 1985; Gould *et al.*, 1989; Shields *et al.*, 1993; Zepeda, 1994; Dorfman, 1996; Westra and Olson, 1997; Cardona, 1999; El-Osta and Morehart, 1999; Soule *et al*., 2000). Both variables were included. Variable AGE accounted for the age of the primary operator and was hypothesized to negatively affect farmers' adoption of BMPs because older operators with shorter planning horizons would be less inclined to adopt new technologies. Dummy variable EDUC accounted for level of education. It took the value of one if the dairy farmer held a college degree and zero otherwise. Educational attainment was expected to improve the decision-making process and enhance adoption. Consequently, EDUC was hypothesized to have a positive sign.

Other factors such as holding an off-farm job (OFFF), having family members who plan to take over the operation upon the farmer's retirement (TOVR), and participation in a dairy cost-sharing program (CSP) such as EQIP were assessed and included as dummy variables. Each variable took the value of one if the producer responded "yes" to the related question in the survey, and zero otherwise. As Feder *et al.* (1985) suggested, off-farm income would permit farmers to overcome the capital constraint and carry out agricultural practices. Hence, variable OFFF was expected to have a positive sign. The existence of family plans to take over the operation upon the farmer's retirement in effect would extend farmers' planning horizons. It would encourage the adoption of conservation practices as farm operators would have an incentive to maintain productivity of soil for future generations (Gould *et al.*, 1989) Therefore, TOVR was expected to increase the adoption of BMPs. Participation in cost-sharing programs likely increases producer involvement in governmental conservation programs. Therefore, variable CSP was expected to be associated with a positive sign.

The last variable that characterizes the dairy producer accounts for his experience in dairy farming. The number of years the dairy farmer had been operating the farm (EXP) was included to capture the increased effect of experience on the adoption decision. Similar to education, experience was expected to improve farmers' ability to adopt new technologies.

3.3.2.2.3. Institutional Variables

Adoption decision making evolves within a multi-stage process where information plays a major role (Freda and Shields, 1980; Anderson, 1993; Moser and Barrett, 2002). A farmer's decision to adopt a management practice is shaped by different sources of information. Training programs provided primarily by the Natural Resource Conservation Service (NRCS) and the Louisiana Cooperative Extension Service (LCES) via programs such as the Modern Farmer Program, would constitute dairy farmers' sources of information regarding environmental issues related to agricultural activities and potential solutions to such problems. More frequent meetings with extension agents would indicate the farmer's reliance on the type of information provided and the likely subsequent acceptance of the recommended practices. Thus, the number of times the farmer met with extension agents in 2000 (LCES) was included as an explanatory variable to capture the increased adoption effect. A dairy farm plan developed with NRCS would suggest the farmer's willingness to comply with environmental standards and, therefore, to adopt conservation practices. Such information was incorporated as a dummy variable (NRCSP) that took the value of one if a plan was developed or updated with NRCS and zero otherwise.

Other sources of information included dairy cooperatives and associations as well as the mass media. A farmer's awareness of other dairy operators' experiences was likely to be important in deciding whether to adopt technology. Many cooperatives promote communication among dairy producers and provide cooperative members information through newsletters, quarterly meetings or other activities. Thus, a dummy variable (COOP) to account for being a member of a dairy cooperative was included. Producers who are better record keepers were also hypothesized to be more willing to adopt conservation practices since they were likely to be more progressive farmers. Dummy variable (DHIA) accounted for being member of the Dairy Herd Improvement Association. DHIA was hypothesized to positively influence the decision to adopt.

Gathering information through seminars and meetings that deal with dairy industry issues constitutes another source of information for dairy farmers. Greater concern for industry issues is likely to enhance adoption of technologies. Number of seminars and/or meetings attended in 2000 (SEM) was expected to positively influence the farmer's decision to adopt.

3.3.2.2.4. Attitudinal Variables

Thurstone's (1928) view of **attitude** as a multidimensional psychological construct that embraces all inclinations and feelings an individual experiences toward a specific subject has been well accepted and restated in attitudinal research literature. The broad extent of liking or disliking something establishes the complex aspect of human attitude. Over time, research findings have emphasized the rationale for linking individual's attitude and behavior (Albrecht and Carpenter, 1976; Werner, 1977; Mueller, 1986; Arcury and Christianson, 1990; Arcury, 1990; Stern *et al.*, 1995; Schultz and Oskamp, 1996). Mueller concluded '…people would routinely behave according to their attitudes and predispositions.' (Mueller, 1986: p. 98).

Unidimensional concepts were developed to account for a particular aspect of a human being's attitude and narrow down the focus to a specific attitudinal object. Seven specific attitudinal variables were included in this study. One variable relates to a dairy farmer's attitude toward risk, another relates to his attitude toward the environment, and five variables describe his social relationships with neighbors, as well as financial and regulatory institutions relevant to dairying activities.

Risk and uncertainty have been discussed in previous empirical studies as impeding factors to technology adoption (Shields *et al,* 1993; Ghosh *et al.*, 1994; Fernandez-Cornejo *et al.*, 1994; Feder *et al.*, 1994; Krause and Black, 1995). These factors urge the risk averse farmer to selectively adopt technology that ensures net expected marginal benefits. In this study, producer's risk aversion was estimated based on the subjective assessment of whether they took substantial levels of risk, neither seek nor avoid risk, or tended to avoid risk whenever possible in their investment decisions. Variable RISK was included as a dummy variable that took the value of 1 if farmer tended to avoid risk and zero otherwise. RISK was expected to increase the adoption of BMPs that reduce soil runoff, insuring long-run viability of land. For some BMPs such as conservation tillage, however, the hypothesized sign may be ambiguous, since conventional tillage has been shown in some uses to reduce yield variability.

Farmer's behavior toward the environment was assessed based on the New Environmental Paradigm (NEP) scale developed by Dunlap *et al.* in 2000. The pool of items considered in the NEP scale includes 15 statements to elicit opinions on five hypothesized features of an ecological worldview, and locate the individual's position on an affective continuum, from a "very positive" to a "very negative" attitude toward the pro-ecological view. The statements are worded in such a way that agreement with the eight odd-numbered items and disagreement with the seven even-numbered ones would denote a pro-ecological worldview. Variable ENV described the NEP score associated with the dairy operator's environmental attitude. It accounted for the dairy producer's average score over the 15 statements. It was expected that environmental concern would drive the farm operator to implement conservation practices.

The concept of **social capital**, introduced by Bourdieu in 1983 and later developed by Coleman (1988), has received researchers' interest over the past two decades. Social capital has been defined in many ways. Coleman emphasized that "social capital is defined by its function. It consists of different entities with two elements in common: the social structure aspects and the facilitation of certain actions of actors." Putman (1995) defined social capital as "the features of social organization, such as networks, norms and social trust, that facilitate coordination and cooperation for mutual benefits." Although researchers have attempted to describe the concept while emphasizing a specific aspect or dimension of social capital in human action, the general perception of social capital as an aggregate concept based on individual's social networks and relationships is well accepted (Coleman, 1988; Putman, 1995; Brehm,1997; Burt, 1997; Paxton, 1999; Schmid, 2000). Research findings have emphasized the critical role of inherent social capital in networks and organizations in community and economic development (Bebbington, 1997; Grant, 2001). Trusting and positive network relationships as well as availability of information inherent in social relations would increase individual capacity for action.

Economists have acknowledged the role of social capital in the conduct of business transactions. Schmid and Robison (1995) defined social capital as "a productive asset which is a substitute for and complement to other productive assets." Peterson *et al.* (1999) discussed the role of trust, reputation and affiliation in creating different types of social capital between business partners. Trust built upon repeated transactions between business partners would influence the establishment of direct social capital. Consistent and reliable transactions would develop reputations, and association affiliation or acquaintanceship would reinforce the establishment of a trusting relationship.

A dairy operator's perception of his social relationships with neighboring farmers (SCAP1), lending institutions (SCAP2), other agricultural businesses (SCAP3), non farmer neighbors (SCAP4) and regulatory agencies (SCAP5) was hypothesized to affect his decision to adopt management practices. The farmer's assessment of his relation with each entity as "not important", "not very important", "somewhat important" and "very important" was scored 0, 1, 2, or 3, respectively. SCAP2 and SCAP5 were hypothesized to increase the adoption of BMPs since important relationships with lending institutions would ensure financial support for the required investment and important relationships with regulatory agency would provide better information regarding the necessity to implement specific management practices. The remaining social capital variables SCAP1, SCAP3 and SCAP4 were included for exploratory purposes.

3.4. Special Computations and Tests

3.4.1. Testing for Multicollinearity

Collinearity problems have received much attention from researchers dealing with multivariate analysis. Collinearity among multiple explanatory variables included in an analysis can impair the interpretation of the effects of a specific variable due to the lack of variability in the data or a nearly exact linear interrelationship among explanatory variables (Judge *et al.*, 1988; Hair *et al.,* 1998). Testing for multicollinearity and taking the appropriate measures to minimize the problem are usually among the first steps in econometric analysis. A collinear relationship between two variables can be ascertained by examining the values of the correlation coefficients and using the rule of thumb of greater than or equal to 0.8 to specify a strong linear association between the two variables.

In the case of multiple variables, it would be more appropriate to investigate the condition indexes associated with the characteristic roots or eigenvalues of the matrix X'X where the X matrix takes into account all the explanatory variables in the model. The condition index can be evaluated using equation (3.25)

$$(3.25) \qquad CI_i = \left[\frac{\lambda_i}{\lambda_k}\right]^{1/2}$$

where λ_i accounts for a specific eigenvalue i, and λ_k represents the largest eigenvalue. A value of the ratio between 30 to 100 or above 100 would indicate a strong or very strong collinearity problem, respectively. The study of the variance proportions matrix allows one to identify the variables associated with the large condition indexes and take appropriate measures to correct the collinearity problem. Diagnostics for multicollinearity were performed using SAS.

3.4.2. Principal Component Analysis (PCA)

PCA was used in this analysis to scale down the large number of potentially relevant explanatory variables included in the empirical model. The use of all 32 variables in the multivariate probit analysis would lead to the problem of too few degrees of freedom and therefore, required the need for fewer variables.

PCA consists of a multivariate technique for examining relationships among several quantitative variables. It allows for exposing linear relationships among a larger set of variables and obtaining fewer uncorrelated components which retain much of the information in the original data (Rao, 1964; Jolliffe, 1972 and 1973; Isebrands and Crow, 1975; Daultrey, 1976; Fomby *et al.*, 1984, Basilevsky, 1994; Hutcheson and Sofroniou, 1999). The PCA technique associates each component to a weighted linear combination of the original variables where the eigenvectors of the correlation or covariance matrix are the coefficients in such linear combination and the eigenvalues of the matrix account for the variance of each component.

The fundamental question in PCA is how to select the components that best describe the structure of the inter-correlations among the original set of variables and discard the remaining components. Different methods have been proposed for discarding variables. Fomby *et al.* (1984) discussed two methods. The first method simply suggests deleting principal components associated with relatively small characteristic roots. Given that the variations in the data are measured by the characteristic roots, such a technique would still preserve as much variation in the data as before. However, the limitation of the method lies in its inability to provide insight on the appropriateness of the restrictions. The second method emphasizes sequential test restrictions implied by deleting components with increasingly large characteristic roots.

Jolliffe (1972 and 1973) investigated the problem of discarding variables using PCA on artificial and actual data. Among other methods, his suggestion of associating one variable with each of the first p components and retaining these variables seemed to give satisfactory results, especially with actual data. The value of p can be set equal to either the number of eigenvalues derived from the correlation matrix greater than λ_0 or the number of components necessary to account for some proportion of the total variation α_0. Jolliffe's findings advocated a suitable level of λ_0 equal to 0.7, but no acceptable value for α_0. Daultrey (1976) also found an optimum value for λ_0 equal to 0.7 in his analysis of the post-War changes in agricultural structure in the Republic of Ireland. Hutcheson and Sofroniou (1999) reported that, "the easiest and most commonly used method is to select any component associated with an eigenvalue greater than 1.0." However, they emphasized the absence of firm rules to establish the optimum number of components, and drew attention to the need for a balance between the amount of variance accounted for and the number of interpretable components.

In this study, two different levels of λ_0 were selected to reduce the number of explanatory variables in the econometric models and dispose of enough degrees of freedom in the estimation. The basic rule for selecting variables considered for the bivariate probit analysis was $\lambda_0 = 0.7$, allowing for the retention of 17 explanatory variables. As more equations were added in the multivariate probit model, a further reduction of the number of variables was crucial. The value of λ_0 was set to 1, yielding 12 variables. Joint tests on the discarded variables were conducted to ascertain the variable selection.

3.4.3. LM Test for Heteroskedasticity

The assumption of homoskedastic error terms is one of the key assumptions in econometric modeling. Errors across observations are assumed to be uncorrelated and to yield a constant variance σ^2. However, when such assumptions do not hold because the covariance between two observations i and j is non zero, the errors are specified as heteroskedastic. In the multiple regression case, heteroskedasticity may still allow one to obtain unbiased and consistent estimators, though not efficient, because the true covariance matrix may be larger. However, heteroskedastic errors in the probit model would greatly impair the analysis. Indeed, estimation with the wrong covariance matrix of the error terms would yield biased and inconsistent maximum likelihood estimators.

The Lagrange multiplier test on the null hypothesis (H_0) of homoskedastic errors was carried out to validate the use of the probit model. Multiplicative heteroskedasticity as specified in (3.26) was assumed to be present.

(3.26) $$\text{var}(e_i) = [\exp(\gamma' w_i)]^2$$

The probit model was considered as the constrained model. The statistical test solely based on the restricted model is presented in (3.27).

(3.27)
$$\begin{cases} H_0 : \gamma = 0 & \Rightarrow \text{ Probit model is appropriate} \\ H_A : \gamma \neq 0 & \Rightarrow \text{ Heteroskedasticity is present and probit model is invalid} \end{cases}$$
$$LM = \left[\frac{\partial \ln L}{\partial \theta} | \hat{\theta}_R\right]' \left[I(\hat{\theta}_R)\right] \left[\frac{\partial \ln L}{\partial \theta} | \hat{\theta}_R\right] \xrightarrow{a} \chi^2_{(q)} \quad \text{under } H_0$$

where θ_R accounts for the estimates obtained from the probit model and q is the number of variables included in matrix W in the multiplicative heteroskedasticity model. The decision rule implies that one fails to reject the null hypothesis of homoskedastic errors when the value of the LM statistic is smaller than the critical value of the χ^2 distribution with q degrees of freedom. Alternatively, a p-value associated with the LM statistic larger than the 5 percent level of significance would lead to the same conclusion of homoskedastic errors. In such a case, one can conclude that the use of the probit model is appropriate. The heteroskedasticity test was conducted for all univariate and bivariate probit models analyzed in this study and a report of all findings is provided.

3.4.4. Goodness of Fit for the Probit Model

Researchers have always shown interest in the assessment of overall goodness of fit of a model and have referred to measure criteria bounded between 0 and 1. A larger value close to 1 is assumed to indicate better fit of the model. The coefficient of determination, R^2, is defined as the proportion of the variation in the dependent variable explained by the regression model. The adjusted R^2, which accounts for the trade-off between increasing the number of variables and losing some degrees of freedom, is also commonly reported in linear regression analyses. In the case of dichotomous dependent variables, different measures have been proposed. McFadden (1973) suggested the likelihood ratio index in equation (3.28) based on the log likelihood for model M_β with regressors and M_α without regressors (except for the constant term).

$$(3.28) \qquad R^2_{McF} = 1 - \frac{\ln \hat{L}(M_\beta)}{\ln \hat{L}(M_\alpha)}$$

Estrella (1998) proposed a measure that would take values in the unit interval and allow the right interpretation at the end points: 0 corresponds to no fit and 1 to a perfect fit. The measure is based on the joint test statistic that all explanatory variables are zero except the constant and would be in accord with the corresponding measure in the linear case. Estrella's measure is presented in equation (3.29).

(3.29) $$R^2 = 1 - \left(\frac{\ln L_u}{\ln L_C} \right)^{-\left(\frac{2}{n}\right)\ln L_c}$$

where $\ln L_u$ represents the log likelihood for unrestricted model (with all regressors) and $\ln L_c$ the likelihood for the restricted model (based on the constant).

The third measure of goodness of fit included in this analysis is referred as the count R^2. It is based on the table of observed and predicted outcomes. The proportion of correct predictions on the diagonal cells of the table give insight of the fit of the model.

(3.30) $$R^2_{count} = \frac{1}{N} \sum_j n_{jj}$$

where n_{jj} represent the correct predictions for outcome j. All three goodness of fit measures are reported in the empirical results in Chapter Four.

3.4.5. Closeness to the True Data Generating Process

The model selection strategy relies on comparing competing models and selecting the one that is "likely to perform best with respect to a particular loss function when using a particular model instead of the true one" (Intriligator *et al.*, 1996, p. 107). Different information measures have been developed, aiming at both the accuracy of the model estimation and the parsimony in the parameters. The Akaike information criteria is one of the criteria frequently reported in applied research. The measure is defined as in equation (3.31).

(3.31) $$AIC = -\frac{2}{N} \ln L_u + \frac{2K}{N}$$

where N represents the number of observations, $\ln L_u$ the value of the log likelihood for the full model and K is the number of parameters in the model. The Akaike criterion suggests maximizing the likelihood functions for each alternative function and selecting the model with the smallest AIC value. The Schwartz criterion, on the other hand, is formulated as:

$$SC = \ln L_u - \frac{1}{2} K \ \ln(N) \tag{3.32}$$

where N, K and $\ln L_u$ receive the same specification as in the Akaike measure. The Schwartz criterion places greater penalty on the dimension of the model and gives preference to the less complex or parsimonious model. The decision rule is to select the model with the largest SC numerical value. Both information measures were reported and discussed in the empirical analysis.

3.4.6. LR Test for Joint Restrictions

Insight into the statistical significance of a particular estimated coefficient can be obtained using the usual t-test. The test examines the significance of the hypothetical assumption that a specific β_j is equal to zero (H_0) against the alternative that it is not, and determines the ratio of the particular estimate to the value of its standard error.

$$\begin{cases} H_0 : \beta_j = 0 \\ H_A : \beta_j \neq 0 \end{cases} \tag{3.33}$$

$$t = \frac{\hat{\beta}_j}{se(\hat{\beta}_j)} \quad \to \quad T_{(N-K)} \quad \text{under } H_0$$

where $\hat{ß}_j$ and sec($\hat{ß}_j$) account for the value and the standard errors of the estimate of β_j, respectively, and N and K for the sample size and the number of explanatory variables included in the model. The decision rule is that one should reject the null hypothesis when the absolute value of the t statistic is greater than the critical value obtained from the t-distribution with N-K degrees of freedom. Alternatively, a p-value associated with the t-statistic smaller than the 5 percent level of significance will imply the same conclusion.

The act of scaling down the number of variables from PCA necessitates the assumption that many of the variables are zero and can be omitted in the probit and multivariate probit analyses. Such linear restrictions on a set of coefficients require more elaborate tests than the one discussed in the previous section. The likelihood ratio (LR) test constitutes one of the three different tests based on the likelihood principle, which are used to analyze joint tests on the parameters β. The Wald test is based solely on the unconstrained model and the Lagrange Multiplier (LM) test on the restricted model. The LR test requires both constrained and unconstrained models. All three tests would be asymptotically equivalent under the null hypothesis that the restrictions hold.

The LR test was conducted to determine whether to reduce the number of explanatory variables in the bivariate and multivariate probit model. The test is specified as:

(3.34)

$$\begin{cases} H_0 : \underline{R}(\theta) = \underline{0} & \Rightarrow \text{ the constrained model is appropriate} \\ H_A : \underline{R}(\theta) \neq \underline{0} & \Rightarrow \text{ at least one of the coefficients is non zero} \end{cases}$$

$$LR = -2 \ \ln\left(\frac{\lambda_R}{\lambda_u}\right) \overset{a}{\rightarrow} \chi_{(J)}^{\ 2} \quad \text{under } H_0$$

where $R(\theta)$ accounts for the joint restrictions, λ_R and λ_u the log likelihood values for the restricted and unrestricted models respectively, and J the number of restrictions. The decision rule infers that one should fail to reject the null hypothesis that the complex restrictions hold when the value of the LR statistic is smaller than the critical value of the χ^2 distribution with J degrees of freedom. Alternatively, a p-value associated with the LR statistic larger than the 5 percent level of significance would imply the same conclusion. Thus, one can conclude that the parsimonious model is more appropriate.

3.4.7. Delta Method

The delta method is a means to determine the asymptotic distribution of a function of the b coefficients, say g(b). The method specified in (3.35) allows for determining the asymptotic variance of g(b) and deriving the standard errors required in the assessment of the statistical significance of the function estimates.

$$\text{If} \quad G = \frac{\partial g(\beta)}{\partial \beta'} \quad \text{then} \quad \text{Est. Asy. Var[g(b)]} = G * V * G' \tag{3.35}$$

$$\text{and} \quad \text{g(b)} \xrightarrow{a} N[g(\beta), G * V * G']$$

where g(b) is the consistent estimator of $g(\beta)$, G is the (J x K) Jacobian matrix of $g(\beta)$ with respect to β' and V the variance of the estimates b. The delta method was used in determining the significance of the marginal effects obtained in the analysis.

3.5. Steps in the Empirical Analysis

In summary, the steps in the analysis are to:

1. Conduct descriptive statistics analysis;
2. Test for multicollinearity;
3. Conduct pincipal component analysis;
4. Conduct probit analysis on each specific best management practice with emphasis on the heteroskedasticity test, goodness of fit, and marginal effects;
5. Select the appropriate model for each BMP to include in the multivariate probit analysis based on the likelihood ratio test;
6. Conduct bivariate probit analyses based on the selected models from previous steps, while stressing the contemporaneous correlation among the error terms, the assumption of homoskedastic errors, and the marginal effects analysis; and

7. Conduct multivariate probit analyses that involve systems of three or more management practices along with the assessment of discrete changes in the probability as an alternative to estimation of marginal effects.

The empirical results from the analysis are presented in the next chapter. Discussion of the results are also provided.

CHAPTER 4

DESCRIPTIVE STATISTICS AND EMPIRICAL RESULTS

This chapter consists of two main parts. The first section provides a general description of dairy producer respondents to the survey. It also includes descriptive statistics related to the NEP scale and the variables included in the econometric models. The second part of the chapter presents a discussion of the results from the univariate, bivariate and multivariate probit analyses.

4.1. Descriptive Statistics

4.1.1. General Characteristics of the Respondents to the Survey

General characteristics of the 124 dairy farm respondents to the mail survey are presented in Table 4.1. The dairy farms were mostly pasture-based operations, located in the southeastern region of Louisiana, especially in St. Helena, Tangipahoa and Washington parishes. Producers have accessed new management technologies such as the computer (40 percent rate of adoption) and artificial insemination (57 percent rate of adoption). The PCDART program and Bovine Somatotropin (BSt) were less adopted among the producers, yielding 16 and 10 percent rates of adoption, respectively.

The sample was comprised of small sized farms with dairy herds between 0 and 49 cows (7 percent), medium-sized farms with dairy herds between 50 and 99 cows (36 percent), large-sized farms with dairy herds between 100 and 149 cows (34 percent), and extra-large farms with more than 150 cows (23 percent). Ninety percent of the dairy farms produced at least at the state average milk production per cow of 12,000 lbs in 2000 (Appendix Table A3). Sixty percent of the dairy farmers had between 100 and 300 acres of land in their farm operations and 31 percent farmed more than 300 acres of land. Twenty-eight percent of the dairy operators owned less than

Table 4.1. General Characteristics of Louisiana Dairy Production in 2000.

Dairy Herd						
Size (Units)	**≤ 50**	**50 to 99**	**100 to 149**	**150 to 200**	**≥ 200**	
Farms [1]	9	44	42	15	14	
%	7	36	34	12	11	
Average Milk per Cow						
Size (10^3 Lbs)	**≤ 10**	**10 to 11.99**	**12 to 13.99**	**14 to 15.99**	**16 to 17.99**	**≥ 18**
Farms [1]	1	12	37	45	20	9
%	1	9	30	36	16	8
Land Included in the Farm Operation						
Size (Acres)	**≤ 100**	**100 to 199**	**200 to 299**	**300 to 399**	**400 to 599**	**≥ 600**
Farms [1]	10	39	36	12	14	13
%	8	31	29	10	11	11
Land Owned by Dairy Farmers						
Size (Acres)	**≤ 100**	**100 to 199**	**200 to 299**	**300 to 399**	**400 to 599**	**≥ 600**
Farms [1]	34 [2]	47	23	6	3	10
%	28 [2]	38	19	5	2	8
Technology Adoption						
Technology	**Computer**	**PCDART** [3]	**BSt** [4]	**AI** [5]		
Farms [1]	49	20	12	71		
%	40	16	10	57		
Type of Dairy Operation						
Type	**Pasture based**	**Free-Stall based**				
Farms [1]	114	10				
%	92	8				
Dairy Farm Location						
Parish	**Beauregard**	**Desoto**	**St Helena**	**Tangipahoa**	**Washington**	**Others** [6]
Farms [1]	4	7	9	48	47	9
%	3	6	7	39	38	7

(1) Number of dairy farms;
(2) Data includes 11 dairy operators (9%) who do not own any land;
(3) PCDART program;
(4) Bovine Somatotropin;
(5) Artificial Insemination; and
(6) Includes the parishes of Bienville, Claiborne, Rapides, St. Landry, Union, and Vernon.

100 acres of the farmland, 57 percent owned between 100 and 300 acres, and 15 percent owned more than 300 acres.

As described in Table 4.2, the survey respondents were mostly male, between 40 and 59 years old, with a high school diploma or a bachelor's degree. Eighty percent of the producers had more than 10 years of experience in dairy farming. The majority of the producers did not hold an off-farm job, but held membership in a milk cooperative.

More than half of the respondents were not aware of the Coastal Nonpoint Control Program (CNCP) nor the effort to control water pollution through the Clean Water Act, as shown in Table 4.3. Forty-eight percent of the producers had heard about BMPs for dairy operations. The producers received information about water quality problems and BMPs primarily from the Louisiana Cooperative Extension Service (LCES), government agencies and farm organizations such as the Farm Bureau. Thirty-five percent of the dairy farms had developed and/or updated a plan with NRCS within the last three years and 52 percent of the producers participated in a cost-sharing program for implementing BMPs.

4.1.2. New Environmental Paradigm Scale

A summary of the distribution of the dairy producers' responses to the NEP statements is presented in Table 4.4. As discussed in the previous chapters, agreement with the eight odd-numbered statements and disagreement with the seven even-numbered items indicate a pro-environmental view. The frequency distribution of the responses shows that more than 50 percent of the dairy producers hold a pro-environmental view regarding statements 2, 3, 5, 7, 8, 9, 11, 13, and 14. Particularly, more than 60 percent of the producers agree with the views in statements 3, 5, 9, and 13 which stipulate the disastrous consequences of human interference with nature, severe human abuse of the environment, humans being subject to the laws of nature,

Table 4.2. Characteristics of Dairy Operators in 2000.

Gender						
Answers	**Male**	**Female**				
Number	112	12				
%	90	10				
Age						
Years	**≤ 30**	**30 to 39**	**40 to 49**	**50 to 59**	**60 to 69**	**≥ 70**
Number	7	14	37	46	14	6
%	6	11	30	37	11	5
Experience in the Dairy Operation						
Years	**≤ 10**	**10 to 19**	**20 to 29**	**30 to 39**	**≥ 40**	
Number	25	29	38	24	8	
%	20	24	31	19	6	
Educational Attainment						
Degree	**NHS** (1)	**High School**	**Technical**	**Bachelor**	**Master**	**Doctoral**
Number	12	70	10	26	6	0
%	10	56	8	21	5	0
Current Generation Operating the Dairy Farm						
Level	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Number	39	50	26	4	4	1
%	32	40	21	3	3	1
Off-Farm Job						
Answers	**Yes**	**No**				
Number	27	97				
%	22	78				
Membership in a Milk Cooperative						
Answers	**Yes**	**No**				
Number	104	20				
%	84	16				
Membership in the Dairy Herd Improvement Association						
Label	**Yes**	**No**				
Number	59	65				
%	48	52				

(1) No High School Diploma.

Table 4.3. Dairy Producers Awareness of Water Quality Issues and BMPS.

Awareness of Coastal Nonpoint Pollution Control Program (CNCP)					
Answers	**Yes**	**No**			
Number	56	68			
%	45	55			
Awareness of the Effort to Control Water Pollution through the Clean Water Act					
Answers	**Yes**	**No**			
Number	95	29			
%	77	23			
Primary Sources of Information about Water Quality Problems					
Sources	**LCES**	**Government Agencies**	**Organization** [1]	**Other Farmers**	
Number	61	39	22	14	
%	49	31	18	11	
Heard about BMPs for Dairy Operations					
Answers	**Yes**	**No**			
Number	59	65			
%	48	52			
Primary Source of Information about BMPs					
Sources	**LCES**	**Government Agencies**	**Organization** [1]	**Media**	**Others**
Number	36	15	12	7	2
%	29	12	10	6	2
Dairy Farm Plan with NRCS within the Last Three Years					
Answers	**Yes**	**No**			
Number	43	81			
%	35	65			
Participation in Cost-Sharing Program for Implementing BMPs					
Answers	**Yes**	**No**			
Number	64	60			
%	52	48			

[1] Farm organizations (Farm bureau, others).

Table 4.4. Frequency Distributions Associated with the NEP Statements.

No	NEP STATEMENTS	Percentage of Responses				
		SA	MA	U	MD	SD
1	We are approaching the limit of the number of people the earth can support…………….……...	18.85	19.67	27.05	20.49	13.94
2	Humans have the right to modify the natural environment to suit their needs…………………...	7.44	26.45	14.88	26.44	24.79
3	When humans interfere with nature it often produces disastrous consequences….………….....	32.23	39.67	7.44	15.70	4.96
4	Human ingenuity will insure that we do NOT make the earth unlivable ………………………………...	14.05	29.75	27.27	14.88	14.05
5	Humans are severely abusing the environment…...	28.10	32.23	14.05	17.36	8.26
6	The earth has plenty of natural resources if we just learn how to develop them.………………………	33.88	45.46	11.57	7.44	1.65
7	Plants and animals have as much right as humans to exist..	30.57	25.62	12.40	17.36	14.05
8	The balance of nature is strong enough to cope with the impacts of modern industrial nations……	8.27	13.22	25.62	25.62	27.27
9	Despite our special abilities, humans are still subject to the laws of nature.……………………..	57.85	28.92	9.92	2.48	0.83
10	The so-called "ecological crisis" facing humankind has been greatly exaggerated ....………………….	16.39	30.33	31.97	12.29	9.02
11	The earth is like a spaceship with very limited room and resources…………………………….....	15.45	30.08	14.63	21.14	18.70
12	Humans were meant to rule over the rest of nature.	38.52	20.49	9.84	13.94	17.21
13	The balance of nature is very delicate and easily upset.…………………………………………….....	29.75	32.23	15.70	17.36	4.96
14	Humans will eventually learn enough about how nature works to be able to control it……………...	2.46	10.65	25.41	26.23	35.25
15	If things continue on their present course, we will soon experience a major ecological catastrophe…	14.05	19.01	32.23	17.35	17.36

and the delicate and easily upset balance of nature. More than 50 percent of the respondents disagreed with statements 2, 8 and 14 related to humans having the right to modify the natural environment to suit their needs, the strength of the balance of nature to cope with the impacts of modern industrial nations, and the eventual ability of humans to control nature. Forty six percent of the respondents agreed with statement 11 regarding the limited space and resources on earth.

Statements 4, 6, 10, and 12 showed a greater percentage of respondents against the environmental view. Indeed, 44 percent of the respondents believed that human ingenuity would insure preservation of a livable earth, 79 percent agreed that "the earth has plenty of natural resources if we just learn how to develop them", 47 percent considered the so-called "ecological crisis" facing humankind as being greatly exaggerated, and 59 percent believed humans were meant to rule over the rest of nature.

Statements 1, 10 and 15 received higher proportions of "unsure" responses. Twenty seven percent of the dairy producers were unsure about the idea that "we are approaching the limit of the number of people the earth can support", 32 percent were uncertain about the ecological crisis statement, and 32 percent were indecisive about an eventual major ecological catastrophe in the near future.

The internal consistency of the NEP scale in this study was assessed using the Cronbach alpha in equation (4.1) where k represents the number of item statements in the scale, s_i^2 the

$$(4.1) \qquad \alpha = \frac{k}{k-1} * \left(1 - \frac{\sum_k s_i^2}{s_T^2}\right)$$

variance of the responses for each item statement, and s_T^2 the variance of total test score. A larger value of alpha indicates inter-correlated test items, in other words, a reliable "internal consistency" of the scale measure (Mueller, 1986; Nunnally and Bernstein, 1994). A coefficient alpha of 0.78 was found. This result indicates reasonable internal consistency of the scale.

4.1.3. Adoption Rates of BMPs

Different rates of adoption were found for each BMP as displayed in Table 4.5. Adoption rates vary across BMP mainly due to a need of greater information or the non applicability of the specific practice to the farm.

Erosion and sediment control practices. Conservation tillage practices had the highest rate of adoption among the management practices targeting the control of soil erosion and sediment transport. Seventy-seven percent of the dairy producers had adopted a tillage practice system to maintain crop residues near soil surfaces. Riparian forest buffers and streambank and shoreline protection were the least adopted in the group, with only 28 percent adoption rates for either practice. The low adoption rates of streambank protection could be because of the few farms having a stream and/or river running through. The survey responses show that 25 percent of the dairy farms had a stream and/or river running through their farm land. The remaining dairy producers had a stream and/or river less than half a mile away from the farm (5 percent), between one half to one mile away from the farm (21 percent), and more than one mile away from the farm (49 percent).

The adoption rates of filter strips and heavy use area protection were 35 and 31 percent, respectively. These results suggest limited establishment of vegetative areas to trap sediment and other pollutants from runoff and wastewater, and/or appropriate surfacing covers to protect frequently and intensively used areas. Grassed waterways and sediment basin management practices had adoption rates of 43 percent. Thus, 43 percent of the respondents had established constructed channels with suitable vegetation to stabilize the conveyance of runoff from water

Table 4.5. Dairy Producers Adoption Rates of BMPs.

Practices	Percentage Adopted	Percentage Not Adopting				NRCS Plan [1]
		Need More Information	High Cost Of Implementation	Have Not Heard Of It	Not Applicable to My Farm	
Erosion and Sediment Control Practices						
Tillage Practices	77	4	3	2	14	18
Cover Crop	38	7	7	15	33	29
Critical Area Planting	46	13	2	12	27	33
Field Borders	48	11	2	8	31	38
Filter Strips	35	17	4	13	31	36
Grassed Waterways	43	10	3	11	33	39
Heavy Use Area Protection	31	17	6	19	27	29
Regulating Water	48	14	4	7	27	35
Riparian Forest Buffer	28	10	1	22	39	40
Sediment Basin	43	9	3	15	30	24
Streambank Protection	28	11	4	8	49	43
Facility Wastewater and Runoff Management						
Roof Runoff Management	34	11	7	15	33	29
Waste System	83	3	2	3	9	0
Waste Storage Facility	70	6	5	2	17	14
Waste Lagoon	78	6	7	2	7	0
Waste Utilization	74	6	6	5	9	0
Nutrient and Pesticide Management						
Nutrient Management	69	7	2	11	11	21
Pesticide Management	62	5	3	7	23	36
Grazing Management						
Fencing	80	4	2	3	11	21
Prescribed Grazing	72	6	0	8	14	33
Trough or Tank	70	3	0	11	16	11

(1) Percentage of respondents answering “BMP Not Applicable to My Farm” who had a plan with NRCS.

concentration, and a similar percentage of producers had built a basin to store manure and waterborne sediment.

The three remaining practices include critical area planting, field borders and regulating water in a drainage system. Their adoption rates were 46, 48 and 48 percent, respectively. These rates suggest that less than half of the dairy producers were involved in the establishment of appropriate vegetation on critically eroding areas, strips of vegetation at the edges of their fields to reduce erosion, or the regulation of water outflow from a drainage system to remove surface runoff.

The low rate of adoption of most practices targeting erosion and sediment control was mainly due to a need of greater information and/or the non applicability of the practice to the farm. More than 10 percent of the respondents did not implement a specific BMP because of insufficient information. The percentage of respondents who had not heard about the BMP at all were between 2 (for tillage practice) and 22 percent (for riparian forest buffer). The "non applicability" responses varied from 14 to 49 percent. The last column of the table shows the percentage of respondents answering "BMP not applicable to my farm" who had a plan with NRCS. The rates were low, suggesting that about two thirds of the respondents answering "non applicable" had not established such a plan.

Facility Wastewater and Runoff Management: This group of practices had received the highest rates of adoption among all BMPs. Eighty-three percent of the producers had installed a planned system to manage runoff from concentrated waste areas. Seventy-eight percent of the producers had installed a waste treatment lagoon to temporarily store and biologically treat wastes from animal and other agricultural activities. Seventy-four percent of the farms had adopted a system to properly utilize waste. The adoption rate of roof runoff management, 34 percent, was the lowest of the group. The stated reasons for such a low rate of adoption were, once again, the lack of information (26 percent) and the non applicability of the BMP to the farm (33 percent).

Nutrient and Pesticide Management. The adoption rates for these practices were 69 and 62 percent, respectively. About 10 percent of the respondents had not heard about these practices. Twenty-three percent of the respondents considered pesticide management not applicable to their farm.

Grazing Management. The group of grazing management practices had high rates of adoption. This may be because of the pasture-based operation type of most of the respondents' dairy operation. Eighty percent of the respondents had a constructed barrier to control and/or exclude livestock and regulate human access. Seventy-two percent of the dairy farms had established a prescribed grazing management plan to improve and maintain controlled harvest of vegetation for grazing animals. However, 8 percent of the producers had not heard of prescribed grazing management, and 14 percent considered the practice not appropriate to their farms. The use of a trough or tank was spread over 70 percent of the dairy farms, but the lack of information and the non applicability of the practice to the farm were the main reasons for non adoption.

4.1.4. The Explanatory Variables

Descriptive statistics related to the farm characteristics variables are presented in Table 4.6. The average number of cows in the respondents' dairy herds was 135. The smallest dairy farm raised 20 cows and the largest raised 600 animals. The kurtosis and skewness measures associated with the COWS variable indicate a relatively peaked distribution with few large values, making the distribution tail off to the right compared to the normal distribution. The average cow productivity was 14,898 lbs of milk with a minimum of 8,100 lbs and a maximum

Table 4.6. Descriptive Statistics of the Farm Characteristic Variables.

Variables	Units	Mean	Std. Dev. [1]	Kurtos. [2]	Skew. [3]	Min.	Max.
COWS	Number	135.169	92.989	10.680	2.813	20	600
YIELD	10^2 Lbs	148.984	22.794	1.015	0.452	81	228
PASTU [4]	0 - 1	0.919	0.273	7.849	-3.118	0	1
OCROP	Number	0.500	0.801	1.556	1.541	0	3
LAND	%	0.663	0.333	-0.688	-0.674	0	1
PART	Number	1.032	1.667	21.940	3.789	0	13
FULT	Number	1.145	1.829	16.614	3.437	0	13
BSTR [5]	0 - 1	0.226	0.420	-0.241	1.328	0	1
NWTH [6]	0 – 1	0.427	0.497	-1.943	0.297	0	1
DEBT [7]	1,2,3,4,5	2.532	1.144	-0.627	0.400	1	5
HEL [8]	1,2,3,4,5	1.774	1.125	1.465	1.502	1	5
WDL [9]	1,2,3,4,5	4.161	1.062	1.136	-1.322	1	5
STRM1 [10]	0 – 1	0.250	0.435	-0.644	1.169	0	1
STRM2 [11]	0 – 1	0.492	0.502	-2.032	0.033	0	1

(1) Standard Deviation; (2) Measure of Kurtosis; (3) Measure of Skewness; (4) 1 for pasture-based operation and zero otherwise; (5) 1 for corporate farm and zero otherwise; (6) 1 for farm net worth ≥ \$400,000 and zero otherwise; (7) 1 for zero debt and 5 for over 60 percent debt ratio; (8) 1 for less than 19 percent of farm land classified as “highly erodible” and 5 for more than 80 percent; (9) 1 for less than 19 percent of farm land classified as “well drained” and 5 for more than 80 percent; (10) 1 for a stream or river running through the farm land and zero otherwise; and (11) 1 for a nearest stream or river at more than one mile from the dairy and zero otherwise.

of 22,800 lbs. Variable YIELD was scaled down by 100 for the regression analyses, to reduce the size difference between explanatory variables. Variable PASTU yielded a mean value of 0.92 and a standard deviation of 0.27. The negative skewness value indicates the relatively small number of farms associated with PASTU values equal to zero. This is consistent with the fact that 92 percent of the dairy farms were pasture-based operations. Most of the dairy farms were not diversified with the exception of a few farms. The percentage of respondents who raised corn, cotton, wheat, soybean, oats, broilers, or beef were, respectively, 19, 1, 2, 4, 8, 2, and 14. Nineteen percent of the respondents were involved in forestry. The average number of other enterprises was 0.5 with a minimum of zero and a maximum of 3 enterprises. The distribution of the OCROP variable is slightly peaked and tailed to the right compared to the normal distribution.

The mean proportion of land owned to total acres of land included in the farm operation was 66 percent with a standard deviation of 33 percent. The distribution of the LAND variable is slightly flat and tailed off to the left compared to the normal distribution. The number of part-time workers varied from zero to 13, with a mean value of 1.03 and a standard deviation of 1.67. The large kurtosis measure indicates a relatively peaked distribution of variable PART compared to the normal distribution. Similar results were obtained with the number of fulltime workers.

Variable BSTR was included as a dummy variable that takes the value of 1 if the dairy farm is structured as a corporation. The mean value of 0.23 confirms the fact that 23 percent of the respondents operated a family or non-family corporation farm. Variable NWTH was incorporated as a dummy variable with a value of 1 for farm net worth greater than or equal to $400,000. The mean value was 0.43 with a standard deviation of 0.5.

Debt to asset ratio was coded as 1, 2, 3, 4, and 5 for values of zero, 1 to 20 percent, 21 to 40 percent, 41 to 60 percent and over 60 percent, respectively. The variable was treated as continuous. Results from the survey indicated that 20 percent of the respondents were debt-free, 33 percent had 1 to 20 percent debt/asset ratios, 26 percent had 21 to 40 percent, 15 percent had 41 to 60 percent and 5 percent had over 60 percent. The DEBT variable has a mean value of 2.5 and a slightly flat distribution, tailed off to the right relative to the normal distribution.

The highly erodible land variable (HEL), also treated as continuous, took the values of 1, 2, 3, 4, and 5 if the percentage of respondents' land fell into the following categories: 0 to 19 percent, 20 to 39 percent, 40 to 59 percent, 60 to 79 percent, or 80 to 100 percent, respectively. Fifty-seven percent of the respondents had less than 20 percent highly erodible land, 23 percent had 20 to 39 percent, 10 percent had 40 to 59 percent, 5 percent had 60 to 79 percent and 5 percent had 80 to 100 percent. The well-drained land variable (WDL) was included as continuous similar to variable HEL. Results show that half of the respondents did not experience major land drainage problems. Only 3 percent of the respondents had less than 20 percent well-drained land, 6 percent had 20 to 39 percent, 10 percent had 40 to 59 percent, 31 percent had 60 to 79 percent, and 49 percent had 80 to 100 percent. Variable WDL has a mean value of 4.16 and a standard deviation of 1.06.

The existence of a stream and/or river on the dairy farm or nearby was accounted for using two dummy variables: STRM1 accounts for a stream or river running through the farm, and STRM2 for the nearest stream or river distant from the farm. Twenty-five percent of the respondents had a stream and/or river running through their farmland. Among the remaining producers who did not have a stream on their farm, 5 percent were half a mile away, 21 percent were between one-half and one mile, and 49 percent were more than one mile away from the nearest stream.

Variables that account for farm characteristics are described in Table 4.7. Respondents to the mail survey were, on average, 51 years old. The youngest producer was 26 and the oldest 78 years old. Twenty-six percent of the respondents had a college degree, 22 percent had an off-farm job, 26 percent had family who planned to take over the operation upon the operator's retirement, and 52 percent participated in a cost sharing program.

Respondents' years of experience in dairy farming were between 2 to 50 years, yielding an average of 23 years. Specifically, 11 percent of the respondents had less than 5 years of experience, 9 percent had 6 to 9 years, 24 percent had 10 to 19 years, 31 percent had 20 to 29 years, 19 percent had 30 to 39 years, and 6 percent had more than 40 years of experience. Variable EXP has a slightly flat and positively skewed distribution.

Descriptive statistics related to the institutional variables are presented in Table 4.8. Eighty-four percent of the respondents held membership in a milk cooperative and 48 percent in the DHIA. Thirty-five percent of the respondents had developed a dairy farm plan with NRCS. The average number of meetings with LCES over the year 2000 was 2.5, with a minimum of zero and a maximum of six meetings. Twenty-six of the respondents did not attend any meetings with LCES in 2000, 38 percent attended 1 or 2, 23 percent attended 3 to 4, and 12 percent attended 4 to 6 meetings. Variable LCES has a relatively flat distribution, tailed off to the right.

Survey responses show that respondents attended, on average, 2 to 3 seminars and/or meetings that dealt with dairy industry issues in 2000, with a maximum of 20 meetings attended. The attendance was as follows: 31 percent of the producers did not attend any meetings at all, 60 percent attended less than 5 meetings, 6 percent participated in 5 to 10, and 3 percent attended

Table 4.7. Descriptive Statistics of the Operator Characteristic Variables.

Variables	Units	Mean	Std. Dev. [1]	Kurtos. [2]	Skew. [3]	Min.	Max.
AGE	Years	50.911	11.582	-0.316	-0.012	26	78
EDUC [4]	0 - 1	0.258	0.439	-0.760	1.119	0	1
OFFF [5]	0 - 1	0.218	0.414	-0.084	1.385	0	1
TOVR [6]	0 - 1	0.258	0.439	-0.760	1.119	0	1
CSP [7]	0 - 1	0.516	0.502	-2.029	-0.065	0	1
EXP	Years	23.169	12.115	-0.611	0.110	2	50

[1] Standard Deviation; [2] Measure of Kurtosis; [3] Measure of Skewness; [4] 1 for having a college degree and zero otherwise; [5] 1 for having an off-farm job and zero otherwise; [6] 1 for a family member planning to take over the dairy farm upon current operator retirement and zero otherwise; and [7] 1 for farmer's participation in any dairy cost-sharing program or zero otherwise.

Table 4.8. Descriptive Statistics of the Institutional Variables.

Variables	Units	Mean	Std. Dev. [1]	Kurtos. [2]	Skew. [3]	Min.	Max.
COOP [4]	0 - 1	0.839	0.369	1.500	-1.865	0	1
DHIA [5]	0 - 1	0.476	0.501	-2.023	0.098	0	1
LCES	Number	2.105	1.803	-0.498	0.594	0	6
NRCSP [6]	0 – 1	0.347	0.478	-1.601	0.652	0	1
SEM	Number	2.540	3.408	11.204	2.916	0	20

[1] Standard Deviation; [2] Measure of Kurtosis; [3] Measure of Skewness; [4] 1 for membership to a dairy (milk) cooperative and zero otherwise; [5] 1 for membership to the DHIA and zero otherwise; and [6] 1 for having developed a dairy farm plan with NRCS within the last three years and zero otherwise.

more than 10 meetings. Variable SEM has a relatively peaked distribution, tailed off to the right because of the few large values.

Descriptive statistics related to the attitudinal variables are presented in Table 4.9. Survey results show that 73 percent of the respondents tended to avoid risk whenever it was possible in their investment decisions, 19 percent neither sought nor avoided risk in their investment decisions, and 8 percent tended to take on substantial levels of risk in their investment decisions.

On average, respondents perceived their social relationships with the different entities related to their farm operation as "somewhat important" to "very important". Each of the five social capital variables has a relatively peaked and negatively skewed distribution compared to the normal distribution. Respondents' average score related to the environmental variable was 3.22 with a standard deviation of 0.61. The lowest value of 1.53 suggest a more anthropocentric view and the largest value of 4.53 indicate a strong pro-environmental attitude. Variable ENV has a slightly peaked and negatively skewed distribution compared to the normal distribution.

4.2. Empirical Results

4.2.1. Test for Multicollinearity

Collinearity among the 32 variables hypothesized as important in determining producers' decisions to adopt BMPs was analyzed using SAS. The collinearity diagnostic consisted of determining the eigenvalues (λ_i), condition indexes (η_i) and the proportion of variation matrix. The procedure was to associate the lowest eigenvalues with condition index values of at least 30 to specific independent variables. A first test was run on the complete set of 32 explanatory variables. Summary of the results, presented in Appendix Table C1, showed four values above 30 at the bottom of the condition indexes column. This suggested a strong collinearity problem

Table 4.9. Descriptive Statistics of the Attitudinal Variables.

Variables	Units	Mean	Std. Dev. [1]	Kurtos. [2]	Skew. [3]	Min.	Max.
RISK	0 - 1	0.734	0.444	-0.866	-1.071	0	1
SCAP1 [4]	0,1,2,3	2.597	0.674	3.918	-1.900	0	3
SCAP2 [5]	0,1,2,3	2.564	0.641	2,872	-1.565	0	3
SCAP3 [6]	0,1,2,3	2.323	0.792	1.467	-1.245	0	3
SCAP4 [7]	0,1,2,3	2.419	0.700	1.773	-1.228	0	3
SCAP5 [8]	0,1,2,3	2.411	0.776	1.786	-1.398	0	3
ENV [10]	Score	3.216	0.611	0.074	-0.244	1.533	4.533

[1] Standard Deviation; [2] Measure of Kurtosis; [3] Measure of Skewness; [4] 0 for relationship with neighboring farmer "not important at all" and 3 for " very important" relationship; [5] 0 for relationship with lending institutions "not important at all" and 3 for " very important" relationship; [6] 0 for relationship with other agricultural businesses "not important at all" and 3 for " very important" relationship; [7] 0 for relationship with non-farmer neighbors "not important at all" and 3 for " very important" relationship; and [8] 0 for relationship with regulatory agencies "not important at all" and 3 for " very important" relationship.

between four variables. Variables YIELD, AGE, SCAP1 and SCAP3 were identified as strongly correlated using the rule of thumb of 50 percent on the sum of the last four lines in each column of the proportion variance matrix. Social relationships with neighboring farmers (SCAP1) as well as other agricultural businesses (SCAP3) were assessed as less important in producers' decisions to adopt and, therefore, were excluded from the set of explanatory variables to reduce the collinearity problem.

A second test was performed using the 30 remaining variables and the results are presented in appendix Table C2. Variables YIELD and AGE remained strongly correlated. The process of discarding variables through principal components analysis constitutes another method for dealing with the collinearity problem. Therefore, all 30 variables were included in the base model for the probit analysis of each individual BMP, but their number was reduced for multivariate probit analysis purposes using PCA.

4.2.2. Principal Component Analysis

Results of the PCA are presented in Appendix D. Two different levels of the eigenvalues (λ_i) were selected based on previous research. First, an optimum eigenvalue of 0.7, as suggested by Jolliffe (1973) and Daultrey (1976), was considered in the process of discarding variables for the parsimonious probit model for each BMP. The process allowed for the retention of 17 variables. The need for further reduction of the number of independent variables required the selection of a larger value of λ equal to 1. The PCA process allowed for the retention of 12 variables necessary for the multivariable probit analyses.

4.2.3. Probit Analysis on Each Specific BMP

Four different models were estimated for each BMP. The base model included all 30 variables retained from the collinearity analysis. The second model incorporated the 17 variables retained from PCA procedure. The third model was an extension of the second model and included extra variables from the base model which were significant at the 10 percent level. The fourth model included variables from the base model which were significant at the 50 percent level. Results of the heteroskedasticity tests showed all Lagrange Multiplier (LM) statistic values associated with very large p-values. Thus, one could conclude that the models were not affected by heteroskedasticity.

The goodness of fit of each model was assessed using McFadden's and Estrella's R^2 statistics. Most of the values were very low, about 0.20, except for the models associated with conservation tillage practices (0.30), streambank protection (0.32), waste management system (0.50), nutrient management (0.33), and prescribed grazing (0.40). AIC and SC criteria were estimated to determine the model closeness to the data generation process.

The conduct of the likelihood ratio test allowed for selecting the relevant parsimonious model to be included in the multivariate analysis. Marginal effects at mean values of all variables as well as at selected values of the dummies were estimated. Finally, discrete changes in the predicted probabilities were assessed for dummy variables with significant coefficients β. The summary of results for the selected model associated with each BMP probit analysis is presented in Table 4.10.

4.2.3.1. Erosion and Sediment Control Practices

The final model for conservation tillage practices included the 17 variables retained from PCA. Seven variables were significant at the 5 or 10 percent level of significance. Variables COWS, YIELD, OFFF, and LCES had the expected positive signs. The magnitude of the marginal effects of COWS and YIELD variables on the probability that a dairy producer would adopt conservation tillage practices were relatively small, about 0.002 and 0.008, respectively.

Table 4.10. Results from the Probit Analysis of Each Individual BMP.

Variables	Conservation Tillage Practices				Cover Green Manure Crop				Critical Area Planting				Field Borders			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-1.2796	-0.2739	-0.4040		-2.4996	-0.9462	-0.9873		-3.4898**	-1.3840**	-1.3370**		-3.2814*	-1.3060*	-1.3038*	
COWS	0.0047*	0.0010*	0.0015*		-0.00005	-0.00002	-0.00002		0.0031*	0.0012*	0.0012*		0.0045**	0.0018**	0.0018**	
YIELD	0.0247**	0.0053**	0.0078**		0.0136**	0.0051**	0.0054**		0.0154**	0.0061**	0.0059**		0.0195**	0.0078**	0.0078**	
STRM1	0.2251	0.0482	0.0711		-0.1615	-0.0611	-0.0638		0.2643	0.1048	0.1013		-0.0059	-0.0023	-0.0023	
HEL	0.1564	0.0335	0.0494		-0.0298	-0.0113	-0.0118		0.1367	0.0542	0.0524		0.0075	0.0030	0.0030	
BSTR	-0.3825	-0.0819	-0.1208		0.1844	0.0698	0.0728		0.0544	0.0216	0.0209		0.1326	0.0528	0.0527	
LAND	-1.2034**	-0.2576*	-0.3800*		0.0278	0.0105	0.0110		-0.3114	-0.1234	-0.1193		-0.1748	-0.0696	-0.0694	
NWTH	-0.1645	-0.0352	-0.0519		0.1017	0.0385	0.0402		-0.2977	-0.1180	-0.1140		-0.3287	-0.1308	-0.1306	
AGE	0.0063	0.0014	0.0020		-0.0109	-0.0041	-0.0043		-0.0087	-0.0035	-0.0033		-0.0032	-0.0013	-0.0013	
OFFF	0.8307**	0.1778**	0.2623*	0.1821**	0.2862	0.1083	0.1130		0.1590	0.0631	0.0609		0.4515	0.1797	0.1794	
TOVR													0.6250*	0.2487*	0.2483*	0.2268**
DHIA	0.0462	0.0099	0.0146		-0.2778	-0.1052	-0.1097		-0.6619**	-0.2625**	-0.2536**	-0.2590**	-0.3768	-0.1500	-0.1497	
COOP	-1.6858**	-0.3608**	-0.5323**	-0.2381**	0.2217	0.0839	0.0876		0.0720	0.0286	0.0276		0.2455	0.0977	0.0976	
LCES	0.3162**	0.0677**	0.0998**		-0.0245	-0.0093	-0.0097		0.1044	0.0414	0.0400		0.1896**	0.0755**	0.0753**	
SEM	0.0037	0.0008	0.0012		0.0180	0.0068	0.0071		0.0194	0.0077	0.0074		0.0348	0.0139	0.0138	
SCAP5	-0.4797**	-0.1027**	-0.1514*		0.0514	0.0194	0.0203		0.1591	0.0631	0.0609		0.0788	0.0313	0.0313	
SCAP2	-0.1251	-0.0268	-0.0395		0.0515	0.0195	0.0203		0.2190	0.0868	0.0839		-0.1577	-0.0628	-0.0627	
RISK	-0.2164	-0.0463	-0.0683		0.4583	0.1735	0.1810		0.1983	0.0786	0.0760		0.3301	0.1314	0.1312	
ENV	0.1697	0.0363	0.0536		-0.0002	-0.00009	-0.00009		-0.0045	-0.0018	-0.0017		0.2108	0.0839	0.0838	
SCAP4													-0.5823**	-0.2318**	-0.2314**	
LM	51.576				18.228				31.026				27.404			
McF	0.288				0.059				0.165				0.176			
Estrella	0.309				0.078				0.220				0.235			
AIC	1.064				1.539				1.443				1.463			
SC	-91.38				-120.81				-114.84				-118.91			
Predicted [a]	98 (79 %)				77 (62%)				94 (76%)				91 (73%)			
LR [b]	LR = 18.81 and X^2 (13) = 22.37				LR = 14.88 and X^2 (13) = 22.37				LR = 11.21 and X^2 (13) = 22.37				LR = 9.03 and X^2 (11) = 19.68			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [a] : Proportion of correct predicted probabilities; and [b] : Log likelihood ratio based on the full model with 30 explanatory variables.

Table 4.10. (Continued).

Variables	Filter Strips				Grassed Waterways				Heavy Use Area Protection				Regulating Water Drainage			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-2.4849	-0.8909	-0.9856		-3.6409**	-1.4244**	-1.2810**		-0.9125	-0.3159	-0.3281		-0.1623	-0.0647	-0.0645	
COWS	0.0035**	0.0012**	0.0014*		0.0018	0.0007	0.0006		0.0003	0.0001	0.0001		0.0024	0.0010	0.0009	
YIELD	0.0172**	0.0062**	0.0068**		0.0208**	0.0081**	0.0073**		0.0050	0.0017	0.0018		0.0003	0.0001	0.0001	
STRM1	-0.3974	-0.1425	-0.1577		-0.4596	-0.1798	-0.1617		0.4475	0.1549	0.1609		-0.0274	-0.0109	-0.0109	
HEL	0.1706	0.0612	0.0677		0.3559**	0.1393**	0.1252**		0.0671	0.0232	0.02411		-0.1905	-0.0759	-0.0757	
BSTR	0.2203	0.0790	0.0874		0.2369	0.0927	0.0834		0.0204	0.0071	0.0073		0.3717	0.1481	0.1477	
LAND	-0.0767	-0.0275	-0.0304		0.5764	0.2255	0.2028		-0.4504	-0.1559	-0.1619		-0.5099	-0.2033	-0.2026	
NWTH	0.0601	0.0215	0.0238		-0.1333	-0.0522	-0.0469		-0.3329	-0.1152	-0.1197		0.4400	0.1754	0.1748	
DEBT									-0.2482*	-0.0859*	-0.0892*					
AGE	-0.0070	-0.0025	-0.0028		0.0072	0.0028	0.0025		0.0073	0.0025	0.0026		-0.0164	-0.0066	-0.0065	
OFFF	-0.3522	-0.1263	-0.1397		-0.2715	-0.1062	-0.0955		0.0574	0.0199	0.0207		0.1318	0.0525	0.0524	
DHIA	-0.5417*	-0.1942*	-0.2149*	-0.1991*	-0.7209**	-0.2820**	-0.2536**	-0.2789**	-0.0448	-0.0155	-0.0161		-0.5424*	-0.2162*	-0.2155*	-0.2104*
COOP	0.0282	0.0101	0.0112		0.0554	0.0216	0.0195		-0.1170	-0.0405	-0.0421		0.6158*	0.2455*	0.2464*	0.2364*
LCES	0.1176	0.0422	0.0466		0.1254*	0.0491*	0.0441*		0.0244	0.0084	0.0088		0.0603	0.0240	0.0240	
SEM	0.0517	0.0185	0.0205		0.0631	0.0247	0.0222		-0.0252	-0.0087	-0.0090		0.0038	0.0015	0.0015	
SCAP5	-0.0403	-0.0145	-0.0160		0.1090	0.0426	0.0383		0.0321	0.0111	0.0116		-0.0619	-0.0247	-0.0246	
SCAP2	-0.1671	-0.0599	-0.0663		-0.3541	-0.1385	-0.1246		0.2466	0.0854	0.0887		0.2414	0.0962	0.0959	
RISK	-0.0306	-0.0110	-0.0121		0.6369*	0.2492*	0.2241**	0.2458*	0.2285	0.0791	0.0821		0.2533	0.1010	0.1006	
ENV	-0.1237	-0.0443	-0.0490		-0.3250	-0.1272	-0.1143		-0.2183	-0.0756	-0.0785		-0.0221	-0.0088	-0.0088	
LM	30.414				31.078				25.733				32.130			
McF	0.178				0.214				0.085				0.123			
Estrella	0.223				0.280				0.105				0.166			
AIC	1.351				1.364				1.446				1.150			
SC	-109.17				-109.92				-116.44				-118.70			
Predicted [a]	98 (79%)				89 (72%)				88 (71%)				87 (70%)			
LR [b]	LR = 8.15 and X^2 (13) = 22.37				LR = 13.82 and X^2 (13) = 22.37				LR = 9.94 and X^2(12) = 21.03				LR = 18.81 and X^2 (13) = 22.37			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [a] : Proportion of correct predicted probabilities; and [b] : Log likelihood ratio based on the full model with 30 explanatory variables.

Table 4.10. (Continued).

Variables	Riparian Forest Buffer				Sediment Basin				Streambank Protection				Roof Runoff Management			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-1.6857	-0.5362	-0.6635		-0.8561	-0.3351	-0.3317		-2.1838	-0.6060	-0.4185		-1.1994	-0.4309	-0.4673	
COWS	0.0010	0.0003	0.0004		0.0016	0.0006	0.0006		-0.0022	-0.0006	-0.0004		0.0032*	0.0011*	0.0012*	
YIELD	0.0075	0.0024	0.0029		0.0034	0.0013	0.0013		0.0069	0.0019	0.0013		0.0011	0.0004	0.0004	
STRM1	0.1908	0.0607	0.0751		-0.0270	-0.0106	-0.0105		0.8911**	0.2473**	0.1708**	0.2616**	-0.1167	-0.0419	-0.0455	
HEL	0.0752	0.0239	0.0296		0.0739	0.0289	0.0286		0.0467	0.0130	0.0089		0.0856	0.0308	0.0334	
BSTR	0.1619	0.0515	0.0637		0.7250**	0.2838**	0.2809**	0.2811**	1.2088**	0.3354**	0.2317**	0.3862**	-0.1533	-0.0551	-0.0597	
LAND	-0.1997	-0.0635	-0.0786		-0.8242*	-0.3226*	-0.3194*		-0.6334	-0.1758	-0.1214		-1.1725**	-0.42128**	-0.4568**	
NWTH	0.1426	0.0454	0.0561		0.4609	0.1804	0.1786		0.6303*	0.1749*	0.1208*		-0.2153	-0.0774	-0.0839	
FULT					0.2890*	0.1131*	0.1120*		-0.3055*	-0.0848*	-0.0586					
AGE	-0.0074	-0.0024	-0.0029		-0.0232*	-0.0091*	-0.0090*		-0.0219	-0.0061	-0.0042		0.0055	0.0020	0.0021	
OFFF	0.0341	0.0108	0.0134		0.6338*	0.2481*	0.2456*	0.2480**	0.0225	0.0063	0.0043		0.5196	0.1867	0.2024*	0.2048*
EDUC									1.3035**	0.3617**	0.2498**	0.4239**				
DHIA	-0.5817*	-0.1850*	-0.2289*	-0.2069*	-0.5325*	-0.2084*	-0.2063	-0.1851*	-0.6245*	-0.1733*	-0.1197	-0.0800	-0.3385	-0.1216	-0.1319	
COOP	0.2825	0.0899	0.1112		0.1853	0.0725	0.0718		0.6285	0.1744	0.1205		-0.1987	-0.0714	-0.0774	
LCES	0.1326*	0.0422*	0.0522*		0.0994	0.0389	0.0385		-0.0137	-0.0038	-0.0026		0.0316	0.0114	0.01232	
SEM	-0.0136	-0.0043	-0.0054		-0.0051	-0.0020	-0.0020		0.0508	0.0141	0.0097		-0.0061	-0.0022	-0.0024	
NRCSP	-0.6237**	-0.1984**	-0.2455*	-0.2194**												
SCAP5	-0.0734	-0.0234	-0.0289		0.0154	0.0060	0.0060		0.1689	0.0469	0.0324		-0.0455	-0.0163	-0.0177	
SCAP2	0.3060	0.0973	0.1204		0.1977	0.0774	0.0766		-0.0838	-0.0233	-0.0161		0.0665	0.0239	0.0259	
RISK	0.4620	0.1470	0.1818		0.6109*	0.2391*	0.2367*	0.2076**	1.3121**	0.3641**	0.2515*	0.1072*	0.2583	0.0928	0.1006	
ENV	-0.2948	-0.0938	-0.1160		-0.1200	-0.0470	-0.0465		-0.0571	-0.0159	-0.0109		0.1767	0.0635	0.0688	
LM	50.557				21.928				45.341				26.208			
McF	0.124				0.209				0.275				0.106			
Estrella	0.145				0.274				0.318				0.133			
AIC	1.349				1.386				1.186				1.436			
SC	-110.45				-112.73				-101.70				-114.38			
Predicted [a]	88 (71%)				86 (69%)				98 (79%)				87 (70%)			
LR [b]	LR = 6.99 and X^2 (12) = 21.03				LR = 6.45 and X^2 (12) = 21.03				LR =15.47 and X^2 (11) = 19.68				LR =6.30 and X^2 (13) = 22.36			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [(a)]: Proportion of correct predicted probabilities; and [(b)]: Log likelihood ratio based on the full model with 30 explanatory variables.

Table 4.10. (Continued).

Variables	Waste Management System				Waste Storage Facilities				Waste Treatment Lagoon				Waste Utilization			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-3.9237	-0.1248	-0.1505		-1.4841	-0.4799	-0.4476		1.0700	0.2874	0.3215		-0.9313	-0.2416	-0.2393	
COWS	0.0120*	0.0004	0.0005		0.0027	0.0009	0.0008		0.0002	0.00006	0.00007		-0.0003	-0.00007	-0.00007	
YIELD	0.0067	0.0002	0.0003		0.0133*	0.0043*	0.0040*		-0.0036	-0.0010	-0.0011		0.0011	0.0003	0.0003	
STRM1	0.9184	0.0292	0.0352		0.2754	0.0891	0.0831		0.4922	0.1322	0.1479		-0.0561	-0.0146	-0.0144	
HEL	0.2287	0.0073	0.0088		0.2263	0.0732	0.0682		-0.0396	-0.0106	-0.0119		0.2780*	0.0721**	0.0714*	
BSTR	0.8048	0.0256	0.0309		0.3232	0.1045	0.0974		-0.3992	-0.1072	-0.1199		0.0260	0.0067	0.0067	
LAND	-1.2755*	-0.0406	-0.0489		-0.5273	-0.1705	-0.1590		-0.3693	-0.0992	-0.1110		-0.2180	-0.0565	-0.0560	
NWTH	0.6661	0.0212	0.0256		0.0862	0.0279	0.0260		0.0362	0.0097	0.0109		0.0270	0.0070	0.0069	
OCROP	0.7589	0.0241	0.0291										0.3621	0.0939	0.0930	
AGE	-0.0314	-0.0010	-0.0012		-0.0241*	-0.0078*	-0.0073*		-0.0082	-0.0022	-0.0025		-0.0176	-0.0046	-0.0045	
OFFF	0.1098	0.0035	0.0042		0.7808**	0.2525*	0.2354*	0.1641**	-0.1198	-0.0322	-0.0360		-0.8556**	-0.2220**	-0.2198**	-0.2930**
EDUC	1.8045**	0.0574	0.0692	0.0037					0.7408*	0.1990*	0.2226	0.1581**				
DHIA	-1.1347**	-0.0361	-0.0435	-0.1364	-0.6279*	-0.2030**	-0.1894**	-0.2250*	0.0776	0.0209	0.0233		0.1439	0.0373	0.0370	
COOP	0.0569	0.0018	0.0022		-0.3425	-0.1107	-0.1033		0.1648	0.0443	0.0495		0.1889	0.0490	0.0485	
LCES	0.1189	0.0038	0.0046		0.1356*	0.0438**	0.0409		0.0392	0.0105	0.0118		0.2033**	0.0528**	0.0522*	
SEM	0.3642**	0.0116	0.0140		0.0362	0.0117	0.0109		0.0562	0.0151	0.0169		-0.0211	-0.0055	-0.0054	
NRCSP													0.9276**	0.2406**	0.2383*	0.1430**
SCAP5	-0.0714	-0.0023	-0.0027		-0.0125	-0.0040	-0.0038		-0.1577	-0.0424	-0.0474		-0.0635	-0.0165	-0.0163	
SCAP2	0.0280	0.0009	0.0011		0.0694	0.0225	0.0209		0.1592	0.0428	0.0478		0.1049	0.0272	0.0269	
RISK	2.0730**	0.0659	0.0795	0.4485*	0.7709**	0.2493**	0.2325**	0.2819**	0.3287	0.0883	0.0988		0.7037*	0.1825*	0.1808*	0.2332*
ENV	0.5993	0.0191	0.0230		0.0331	0.0107	0.0100		0.0532	0.0143	0.0160		-0.0149	-0.0039	-0.0038	
SCAP4													0.3221	0.0836	0.0827	
LM	44.312				38.864				36.630				47.270			
McF	0.501				0.194				0.113				0.259			
Estrella	0.468				0.231				0.118				0.290			
AIC	0.777				1.273				1.124				1.185			
SC	-76.360				-104.32				-103.45				-103.09			
Predicted [a]	113 (91%)				96 (77%)				101 (81%)				98 (79%)			
LR [b]	LR = 3.89 and $X^2(11) = 19.68$				LR = 10.10 and X^2 (13) = 22.36				LR = 8.41 and X^2 (11) = 19.68				LR =5.09 and X^2 (10) = 18.31			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5%; * : Values significant at 10%; [a]: Proportion of correct predicted probabilities; and [b]: Log likelihood ratio based on the full model with 30 explanatory variables.

Table 4.10. (Continued).

Variables	Nutrient Management				Pesticide Management			
	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-2.7966	-0.8517	-0.3841		-4.1770**	-1.55888**	-1.6658**	
COWS	-0.0054*	-0.0016*	-0.0007		0.0003	0.00009	0.00009	
YIELD	0.0170**	0.0052**	0.0023*		0.0089	0.0033	0.0035	
STRM1	-0.3907	-0.1190	-0.0537		0.7519*	0.2806*	0.2998*	0.2765*
HEL	0.0854	0.0260	0.0117		-0.0143	-0.0053	-0.0057	
BSTR	0.0208	0.0063	0.0029		0.1911	0.0713	0.0762	
LAND	-0.5179	-0.1577	-0.0711		-0.1531	-0.0572	-0.0611	
NWTH	0.2381	0.0725	0.0327		-0.0993	-0.0370	-0.0396	
PASTU					0.7318	0.2731	0.2919	
OCROP	0.1102	0.0336	0.0151					
FULT	0.5661**	0.1724**	0.0777*					
STRM2					0.5352	0.1997	0.2134*	
AGE	-0.0029	-0.0009	-0.0004		0.0206	0.0077	0.0082	
OFFF	0.2295	0.0699	0.0315		0.0836	0.0312	0.0333	
EDUC					0.9207**	0.3436**	0.3672**	0.3250**
EXP					-0.0258*	-0.0097*	-0.0103*	
DHIA	-1.0761**	-0.3277**	-0.1478**	-0.2783**	-0.2972	-0.1109	-0.1185	
COOP	0.8856**	0.2697**	0.1216*	0.2106	-0.0144	-0.0054	-0.0057	
LCES	0.3084**	0.0939**	0.0424*		0.0605	0.0226	0.0241	
SEM	0.0107	0.0032	0.0015		-0.0068	-0.0025	-0.0027	
SCAP5	-0.1277	-0.0389	-0.0175		0.3556*	0.1327*	0.1418*	
SCAP2	0.5021**	0.1529**	0.0690		-0.2856	-0.1066	-0.1139	
RISK	0.4862	0.1481	0.0668		0.4411	0.1646	0.1759	
ENV	-0.2937	-0.0894	-0.0403		0.3347	0.1249	0.1335	
LM	25.646				21.468			
McF	0.276				0.126			
Estrella	0.331				0.163			
AIC	1.224				1.515			
SC	-104.12				-124.98			
Predicted [(a)]	98 (79%)				82 (66%)			
LR [(b)]	LR = 6.86 and $X^2(11) = 19.68$				LR = 6.58 and $X^2(9) = 16.92$			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ: Discrete changes for specific dummies; **: Values significant at 5%; * : Values significant at 10%; [(a)] : Proportion of correct predicted probabilities; and [(b)] : Log likelihood ratio based on the full model with 30 explanatory variables.

Table 4.10. (Continued).

Variables	Fence				Prescribed Grazing				Trough or Tank			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	0.3830	0.0944	0.0620		0.2727	0.0731	0.0864		-1.3830	-0.4507	-0.3874	
COWS	0.0008	0.0002	0.0001		0.0014	0.0004	0.0004		-0.0008	-0.0003	-0.0002	
YIELD	0.0067	0.0017	0.0011		0.0028	0.0008	0.0009		0.0055	0.0018	0.0015	
STRM1	-0.0465	-0.0115	-0.0075		0.1342	0.0360	0.0425		0.1797	0.0586	0.0503	
HEL	-0.0042	0.0010	-0.0007		0.0252	0.0068	0.0080		0.1242	0.0405	0.0348	
BSTR	0.2944	0.0725	0.0477		0.3468	0.0929	0.1098		0.0517	0.0169	0.0145	
LAND	0.4273	0.1053	0.0692		-1.6157**	-0.4330**	-0.5116**		-0.3256	-0.1061	-0.0912	
NWTH	0.1030	0.0254	0.0167		0.3349	0.0897	0.1060		0.0274	0.0089	0.0077	
PASTU					1.0278*	0.2754*	0.3255*	0.3878*				
PART					-0.1793	-0.0481	0.0568					
AGE	-0.0408**	-0.100**	-0.0066**		-0.0248	-0.0066	-0.0079		0.0021	0.0007	0.0006	
OFFF	-0.3691	-0.0909	-0.0598		0.0449	0.0120	0.0142		0.0379	0.0124	0.0106	
CSP					-0.7658**	-0.2052**	-0.2425	-0.1742*				
DHIA	-0.2721	-0.0670	-0.0441		-0.5610	-0.1503	-0.1776		-0.1052	-0.0343	-0.0295	
COOP	0.6007	0.1480	0.0973		-0.0128	-0.0034	-0.0041		0.6575*	0.2143*	0.1842*	0.2270
LCES	0.0923	0.0227	0.0150		0.3775**	0.1012**	0.1195**		0.0751	0.0245	0.0210	
SEM	-0.0063	-0.0016	-0.0010		-0.0060	-0.0016	-0.0019		0.1267*	0.0413*	0.0355*	
SCAP5	0.2407	0.0593	0.0390		-0.1088	-0.0292	-0.0344		0.0276	0.0090	0.0077	
SCAP2	0.0751	0.0185	0.0122		0.0778	0.0209	0.0246		0.1177	0.0383	0.0330	
RISK	0.5752*	0.1417*	0.0932	0.1317	0.2830	0.0758	0.0896		0.4718	0.1538	0.1322	
ENV	-0.1495	-0.0368	-0.0242		0.0408	0.0109	0.0129		-0.1773	-0.0578	-0.0497	
SCAP4					0.3702	0.0992	0.1172					
LM	46.349				54.976				49.925			
McF	0.135				0.3530				0.129			
Estrella	0.136				0.4044				0.155			
AIC	1.160				1.125				1.353			
SC	-97.28				-100.76				-109.24			
Predicted [a]	100 (81%)				103 (83%)				94 (76%)			
LR [b]	LR = 8.42 and $X^2(13) = 22.36$				LR = 5.60 and $X^2(9) = 16.92$				LR = 8.42 and $X^2(13) = 22.36$			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [a] : Proportion of correct predicted probabilities; and [b] : Log likelihood ratio based on the full model with 30 explanatory variables.

The negative sign for variable LAND could be due to the larger percentage of owned land among smaller-sized farms that did not adopt conservation tillage practices. Holding other variables constant, a one percent increase in land owned would likely reduce the probability of adopting conservation tillage practices by 38 percent, and membership in a milk cooperative would decrease the probability by 23 percent. Having an off-farm job would, on the other hand, increase the probability of adopting by 18 percent. This is not surprising since conservation tillage generally requires less labor than conventional tillage, and the off-farm employee is likely to be labor-constrained. The model also shows that producers who rated relationships with regulatory agencies as more important were less likely to adopt, as suggested by the 15 percent decrease in the probability of adopting conservation tillage, associated with variable SCAP5. Such result was not as initially expected.

The model for the cover green manure crop practice included the 17 variables from the PCA. YIELD was the only significant variable, though the effect was very small. A 100 pound increase in cow productivity would increase the probability of adopting the practice by 0.5 percent, holding other variables constant. COWS, YIELD and membership in DHIA significantly influenced the adoption of the critical area planting practice. The negative sign of the DHIA variable was not as initially expected. The effect may be because of the purposes of DHIA in enhancing dairy operation productivity and ensuring higher profit through highly monitored business management. Adoption of conservation practices, on the other hand, aims at an overall improvement of the environment which would ensure long term financial outcomes. Thus, adoption of this BMP (and others as will later be seen) may not be consistent with the goals of profit maximizing producers. Membership in DHIA would likely reduce the probability of adopting critical area planting by 26 percent, holding the other variables constant.

The probit model for the field borders practice included 19 explanatory variables, five of which significantly influenced the probability of adopting the practice. The positive effects of COWS, YIELD, TOVR, and LCES variables were as expected. With respect to the negative effect of SCAP4 variable, a good relationship with non-farmer neighbors would reduce the probability of establishing perennial vegetation at the edge of the field by 23 percent, holding the other variables constant. This may be due to a perception that such vegetation is unsightly and, thus, un-neighborly. Having any family member planning to take over the farm operation upon the producer's retirement would likely increase the probability to establish field borders by 23 percent, holding the other variables constant.

Variables COWS, YIELD and DHIA significantly affected the adoption of filter strips. The magnitude of the positive effects of COWS and YIELD were again relatively small, about 0.001 and 0.007, respectively. Membership in DHIA would decrease the probability of establishing vegetative areas to trap sediment, organic material, nutrients and chemicals from runoff by 20 percent, holding other variables constant.

The adoption of grassed waterways was significantly influenced by five variables: YIELD, HEL, DHIA, LCES, and RISK. The signs of the effects were as expected. A twenty percent increase in farmland classified as "highly erodible" would result in an increased probability to construct grassed waterway channels of 13 percent, holding other variables constant. One additional meeting with LCES and producer's risk aversion would likely increase the adoption by 4 and 25 percent, respectively, holding the other variables constant. The risk averse producer might adopt grassed waterways to reduce the potential negative impact of a heavy rain event on the long-run productivity and economic viability of the land.

Producers' decisions to stabilize frequently and intensively used areas were significantly affected by the level of their debt/asset ratio. A twenty percent increase in the ratio would likely decrease the probability of protecting heavy use areas by 9 percent, holding the other variables constant.

Memberships in milk cooperatives as well as in DHIA had significant impacts on the adoption of regulating in a water drainage system. The effects, although similar in magnitude, were in the opposite direction. DHIA would likely reduce the probability to adopt the practice by 21 percent, whereas COOP would likely enhance the adoption by 24 percent, holding the other variables constant. Many COOP newsletters inform producers about dairy management issues, allowing them to make better informed management decisions.

Three variables significantly affected the adoption of riparian forest buffers. Membership in DHIA, and a plan established with NRCS would likely decrease the probability to establish buffer zones adjacent to and uphill from water bodies by 21 and 22 percent, respectively. An additional meeting with LCES, on the other hand would enhance the adoption by 5 percent.

Seven variables significantly influenced the construction of sediment basins. Business structured as a corporation, number of fulltime workers, the holding of an off-farm job, and farmer's risk aversion were associated with increased adoption of the practice. Increases in the probability to construct a sediment basin associated with these three dummy variables were 28, 25 and 21 percent, respectively. Having one additional fulltime worker would increase the probability of constructing sediment basins by 11 percent. On the other hand, a larger percentage of land owned, age and membership in DHIA reduced the adoption. A one unit increase in the percentage of land owned, one year of age older, and membership in DHIA would reduce the probability to construct sediment basins by 32, 0.9 and 19 percent, respectively.

The positive effects of having a stream and/or river running through the farmland, business structured as a corporation, higher net worth, education and risk aversion on the establishment of vegetation or structures to protect banks of streams from erosion were as expected. The increased effects on the probability of protecting streambanks and shorelines, associated with these four variables were 26, 38, 42, and 11 percent, respectively. The hiring of one additional fulltime worker and membership in DHIA would reduce the probability of adoption by 6 and 8 percent, respectively.

4.2.3.2. Facility Wastewater and Runoff Management Practices

Having a larger sized farm and the holding of an off-farm job enhanced the adoption of roof runoff management. These two variables were associated with marginal increases of 0.1 and 20 percent, respectively, in the probability to adopt the practice. A one percent increase in the land owned would reduce the probability to manage roof runoff by 46 percent.

The probit model for the waste management system included 20 variables, six of which had significant β coefficients. However, their effects on the probability to adopt the practice were not significant except for the RISK variable. Producer's aversion to risk would increase the probability of adopting a system to manage waste by 45 percent.

Four variables significantly and positively influenced the increased construction of a waste storage impoundment. Cow productivity, the holding of an off-farm job, frequency of meetings with LCES and farmers' risk aversion increased the probability of adopting a waste storage facility. These variables were associated with an increased probability of constructing a waste impoundment of 0.4, 16, 4, and 28 percent, respectively, holding the other variables constant. On the other hand, Age and DHIA membership negatively affected the adoption. One year of age older and membership in DHIA would decrease the probability to adopt by 0.7 and

23 percent, respectively. The probit model for waste treatment lagoon included 20 variables. Producer's educational attainment was the only variable that significantly influenced producer's adoption of the practice. Having a college degree would increase the probability of adopting by 16 percent.

Higher percentage of farmland classified as "highly erodible", frequency of meetings with LCES, the establishment of a dairy farm plan with NRCS, and farmer's risk aversion were associated with proper utilization of wastes. The increased effects on the probability of adoption were 7, 14 and 23 percent, respectively. The holding of an off-farm job would reduce the probability of adopting the practice by 29 percent. The spreading of manure is very labor intensive, perhaps preventing producers with off farm employment from doing it.

4.2.3.3. Nutrient and Pesticide Management

The probit model for nutrient management included 19 variables and six variables were found to significantly influence farmers' decisions to adopt the practice. Milk yield, the number of full time employees, membership in a milk cooperative, frequency of meetings with LCES, and a good relationship with lending institutions were associated with greater implementation of nutrient management. A higher number of cows and membership in DHIA would likely decrease the adoption of nutrient management. The effect of cows is surprising, given the increased scrutiny of regulatory agencies, especially with respect to larger operations.

The existence of a stream and/or river running through the farm, higher educational attainment and good a relationship with regulatory agencies were found to be positively associated with enhanced adoption of pesticide management. Dairy producers who have been in business longer have likely become more accustomed to existing practices and less likely to change, thus explaining the negative coefficient on experience.

4.2.3.4. Grazing Management

The probit model for fencing practice included the 17 variables retained from the PCA. Age and risk aversion were the two variables which significantly influenced the dairy producers' adoption of the practice. One year of age older would decrease the probability of adopting by 7 percent, whereas, risk aversion would increase the adoption by 13 percent.

Producers operating a pasture-based dairy farm and meeting frequently with LCES personnel would be more likely to adopt prescribed grazing. The increased effects of the PASTU and LCES variables on the probability that a dairy producer would establish a prescribed grazing plan would be 39 and 12 percent, respectively. A one percent increase in land owned and participation in a cost-sharing program would reduce the probability of adopting by 51 and 17 percent, respectively. These negative effects of LAND and CSP are not as initially expected. Membership in a milk cooperative and frequent attendance of seminars and/or meetings that dealt with dairy industry issues were associated with greater implementation of livestock watering facilities such as a trough or tank. These variables were associated with 22 and 4 percent increases in the probability of adopting, respectively.

4.2.4. Bivariate Probit Analysis

The simultaneous adoption of two BMPs was examined in this section. The system of two equations in the bivariate probit model was based on the selected models from the univariate probit analysis. The group of practices which aimed at erosion and sediment control was divided into two subcategories according to whether they targeted primarily erosion reduction or sediment control. In total, 38 bivariate models were estimated for the 21 BMPs, as shown in Table 4.11. Twenty-one models were explored for the seven practices included in the subgroup of practices targeting the reduction of erosion, and six models were analyzed for the group of practices for sediment control. Waste storage facility, waste treatment lagoon, and waste utilization were considered as nested in the waste management system. Therefore, the number of bivariate estimations was reduced to 7 for the group of practices dealing with facility wastewater and runoff management. The 4 remaining estimations concerned nutrient and pesticide management and the grazing management practices.

Thirty-two of the rho coefficients were found significant at the 5 or 10 percent levels of significance. Results also showed few strong correlations of 0.8 or more. Comparison of the initial frequency of dependent variable outcomes (0,0), (0,1), (1,0) and (1,1) with the fitted values provided information about model predictability. The bivariate probit models for the group of practices targeting erosion and sediment control tended to heavily predict the adoption of neither practices under consideration. This may be due to the low adoption rate of most of the erosion and sediment control practices. Marginal effects of the explanatory variables were estimated conditional on the adoption of one practice. All the Lagrange Multiplier statistical values were associated with very large p-values, allowing one to conclude no problem with heteroskedasticity. The goodness of fit of the model was assessed using the pseudo-R^2 measure used by Lim-Applegate *et al*. (2002).

Selected results for the bivariate probit models are summarized in Table 4.12. The bivariate probit model for field borders and grassed waterways included in total 38 independent variables. The holding of an off-farm job, plans for a family member to take over the dairy operation upon the farmer's retirement, frequency of meetings with LCES personnel, and good relationships with non-farmer neighbors were associated with an increased joint adoption of field borders and grassed waterways. The negative effect of variable SCAP4 on the conditional probability of establishing any field borders given that grassed waterways practice was adopted,

Table 4.11. Rho Coefficients for the Bivariate Probit Analysis.

PRACTICES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CTILL (1)	1																				
GMANU (2)	0.406*	1																			
CAREA (3)	0.791**	0.366**	1																		
FIELB (4)	0.580**	0.521**	0.697**	1																	
GRSW (5)	0.453	0.582**	0.660**	0.796**	1																
HVUSE (6)	0.665**	0.623**	0.605**	0.738**	0.796**	1															
RWAT (7)	0.295	0.341**	0.342**	0.561**	0.299	0.476**	1														
FILTS (8)								1													
RIFOBU (9)								0.746**	1												
SEDB (10)								0.345*	0.566**	1											
STRMP (11)								0.439*	0.855**	0.715**	1										
ROOFR (12)												1									
WSTF (13)												0.403*	1								
WSTL (14)												0.162	0.775**	1							
WSTUT (15)												0.732**	0.931**	0.996**	1						
WSTS (16)												0.572	-	-	-	1					
NMNG (17)																	1				
PMNG (18)																	0.668**	1			
FENCE (19)																			1		
PGRAZ (20)																			0.820**	1	
TROUG (21)																			0.777**	X	1

**: Values significant at 5%; *: Values significant at 10%; - : Models were not estimated because of the assumption of nested models; X: Problem of singular covariance matrix.

Table 4.12. Selected Results from the Bivariate Probit Analysis.

Variables	FILDB- GRSW				WSTF-WSTUT				NMNG-PMNG				PGRAZ-FENCE			
	B1	B2	M1	M2	B1	B2	M1	M2	B1	B2	M1	M2	B1	B2	M1	M2
ONE	-3.3770	-3.6430*	-0.4746	-0.7365	-0.9588	0.2992	-0.3506	0.1608	-2.8665	-3.8109	-0.2526	-0.9719	-0.5356	0.5557	-0.1699	0.1412
COWS	0.0057**	0.0017	0.0019	-0.0007	0.0029	-0.0002	0.0009	-0.0004	-0.0038	0.0001	-0.0009	0.0005	0.0023	0.0008	0.0004	-0.0001
YIELD	0.0207**	0.0189**	0.0037	0.0030	0.0110	0.0034	0.0027	-0.0008	0.0181	0.0082	0.0032	0.0005	0.0059	0.0089	0.0003	0.0010
STRM1	0.0814	-0.5280	0.1633	-0.2566	0.4419	0.1023	0.1139	-0.0358	-0.4993	0.6884	-0.1841	0.3130*	0.1795	-0.1277	0.0510	-0.0374
HEL	-0.0331	0.3624**	-0.1028	0.1702**	0.1242	0.2429	-0.0106	0.0241	0.1003	-0.0211	0.0248	-0.0211	0.0134	-0.0224	0.0051	-0.0050
BSTR	0.2118	0.2907	0.0144	0.0739	0.2832	0.0197	0.0821	-0.0302	0.0633	0.1913	-0.0055	0.0597	0.3506	0.2846	0.0450	0.0174
LAND	-0.1363	0.4386	-0.1636	0.2312	-0.5167	-0.4819	-0.0611	-0.0160	-0.5961	-0.1175	-0.1224	0.0386	-1.5736	0.5364	-0.3872*	0.2293
NWTH	-0.2671	-0.1232	-0.0782	0.0152	0.1059	-0.0381	0.0397	-0.0186	0.3219	-0.1106	0.0841	-0.0829	0.2078	0.0796	0.0358	-0.0048
PASTU						-0.8289	0.1647	-0.1323		0.6988	-0.0724	0.2492	1.1673*		0.2466	-0.1027
OCROP									0.0092		0.0021	-0.0012				
PART													-0.1987		-0.0420	0.1748
FULT									0.4388		0.0991	-0.0593				
STRM2										0.4105	-0.0425	0.1464				
AGE	-0.0048	0.0065	-0.0036	0.0042	-0.0219	-0.0140	-0.0039	0.0003	-0.0031	0.0169	-0.0024	0.0064	-0.0268	-0.0418*	-0.0014	-0.0047
OFFF	0.5532	-0.3287	0.3060*	-0.2918	0.7196	-0.8197*	0.3814*	-0.2157	0.2472	0.0848	0.0470	-0.0031	0.1422	-0.4241	0.0733	-0.0843
CSP													-0.8435		-0.1782	0.0742
EDUC						0.4456	-0.0886	0.0711		0.8627	-0.0894	0.3077				
TOVR	0.6555*		0.2665*	-0.1722												
EXP										-0.0200	0.0021	-0.0071				
DHIA	-0.3514	-0.7515	0.0425	-0.2426	-0.5498	0.1903	-0.2048	0.0952	-1.0692*	-0.3163	-0.2087*	0.0316	-0.6237	-0.4298	-0.0879	-0.0179
COOP	0.3387	0.0397	0.1279	-0.0712	-0.3397	0.0707	-0.1172	0.0513	0.8009	-0.0278	0.1838	-0.1181	-0.1748	0.5171	-0.0897	0.1029
LCES	0.2399**	0.1138	0.0695*	-0.0123	0.1294	0.1561	0.0083	0.0097	0.2622*	0.0593	0.0531	-0.0143	0.3599**	0.0735	0.0685**	-0.0192
SEM	0.0178	0.0525	-0.0057	0.0187	0.0365	-0.0029	0.0117	-0.048	0.0155	-0.0053	0.0041	-0.0040	-0.0080	-0.0046	-0.0012	-0.0001
SCAP5	0.1097	0.1305	0.0124	0.0293	-0.0346	-0.1012	0.0096	-0.0121	-0.1010	0.3293*	-0.0569	0.1311	-0.1897	0.2943	-0.0701	0.0665
SCAP2	-0.1754	-0.2599	-0.0072	-0.0698	0.0366	0.1011	-0.0090	0.0118	0.4176	-0.2697	0.1222	-0.1526	0.1657	0.0423	0.0307	-0.0074
RISK	0.4136	0.5683	0.0280	0.1446	0.6920	0.5969	0.0915	0.0137	0.5152	0.3361	0.0815	0.0503	0.2905	0.5578	0.0044	0.0689
ENV	0.1770	-0.2360	0.1302	-0.1517	0.0123	-0.0573	0.0151	-0.0106	-0.2575	0.3489	-0.0943	0.1592	0.1365	-0.2395	0.0533	-0.0526
SCAP4	-0.7339**		-0.2984**	0.1927*		0.2694	-0.0535	0.0430					0.4310		0.0910	-0.0379
RHO	0.7954*				0.9309*				0.6808*				0.8204*			
Frequency	51 (a)	14 (b)	20 (c)	39 (d)	22 (a)	15 (b)	10 (c)	77 (d)	26 (a)	13 (b)	21 (c)	64 (d)	15 (a)	20 (b)	10 (c)	79 (d)
Fitted Values	68 (a)	7 (b)	9 (c)	40 (d)	13 (a)	7 (b)	7 (c)	97 (d)	15 (a)	8 (b)	10 (c)	91 (d)	10 (a)	14 (b)	0 (c)	100 (d)
LM	89.480				105.958				99.08				105.92			
Pseudo R^2 (e)	0.209				0.216				0.197				0.274			

B1: Coefficients for first practice 1; B2: Coefficients for first practice 2; M1: Marginal effects at mean values of all variables on P[y1|y2=1]; M2: Marginal effects at mean values of all variables on P[y2|y1=1]; **: Values significant at 5%; *: Values significant at 10%; (a), (b), (c), (d) Correspond to the frequence and fitted values for (0,0), (0,1), (1,0) and (1,1), respectively. (e) Pseudo-R^2 =1–(Lu/Lr) where Lu and Lr are the log likelihood values for the unrestricted model (LnL($)) and restricted model (LnL(one)) (Lim-Applegate *et al.*, 2002).

is similar to that encountered in the univariate probit model for field borders. A good relationship with non-farmer neighbors would reduce the probability of establishing perennial vegetation at the edge of the field by 29 percent if grassed waterways had been established. On the other hand, percentage of farm land classified as "highly erodible" and good relationships with neighbors were associated with increased construction of grassed waterways by dairy farmers who had established field borders.

The model for waste storage facility and waste utilization included 39 variables. The distribution of the fitted values associated the model with higher predictions on the adoption of both practices (78 percent) and relatively less on the adoption of neither one (10 percent) compared to the initial frequency of the dependent variable outcomes. The holding of an off-farm job was the only variable which significantly affected the adoption of both practices. It increased the probability of constructing temporary storage impoundments given that the dairy producers had adopted proper utilization of wastes by 38 percent.

The model for nutrient and pesticide management included 42 variables in total. The rho coefficient of 0.68 was significant at the 5 percent level of significance. The model predicted an increased adoption of both practices simultaneously. Three variables were found to significantly affect the joint adoption. The directions of the effects, reflected in the signs of the estimated coefficients, were consistent with the findings in the probit analysis of each BMP. Membership in DHIA likely reduced the implementation of nutrient management if the dairy farmer had adopted pesticide management. Having a stream and/or river running through the farm likely increased the adoption of pesticide management by dairy farmers who had a nutrient management plan.

The bivariate probit model for prescribed gazing and fencing practices had a rho coefficient of 0.82, significant at the 5 percent level. This model also predicted a higher percentage (81 percent) of adopting both practices simultaneously compared to the initial frequency of the dependent variables outcomes. The signs of the coefficients associated with variables PASTU, AGE and LCES were similar to those in the univariate probit models. One additional meeting with LCES personnel would increase the establishment of a prescribed grazing plan by dairy farmers who had fenced their land by 7 percent. One percent additional land owned to total land in the farm operation would decrease the adoption by 39 percent.

4.2.5. Multivariate Probit Analysis

The simultaneous adoption of larger sets of BMPs in each subgroup of practices were examined in this section. Variables to be included in the system of 3 to 6 equations in the multivariate probit analysis were determined using 4 different scenarios. In the first scenario, variables were based on the selected models from the univariate probit analysis. In scenario two, each equation incorporated the 12 variables obtained from the PCA $(\lambda = 1)$. These models were extended in scenario three by including other variables significant at least at the 10 percent level, from the probit analysis of each BMP. Models in scenario four included variables from the probit analysis, which were significant at least at the 50 percent level of significance. Discrete changes in the probability of adopting all practices under consideration were estimated as alternative to marginal effects of variables associated with coefficients with significance at least at the 10 percent level.

4.2.5.1. Erosion and Sediment Control Practices

Two sets of models were considered for the group of practices targeting erosion reduction labeled category I in Table 4.13. Conservation tillage was left out because of its relatively high rate of adoption compared to the remaining practices in the group. Indeed, conservation tillage was adopted at the rate of 77 percent while the adoption rates of the remaining erosion and sediment practices were from 28 to 48 percent. Such a difference would affect the estimation.

The first set of models included six equations associated with the following practices: cover and green manure crop (GMANU), critical area planting (CAREA), field borders (FILDB), grassed waterways (GRSW), heavy use area protection (HVUSE) and regulating water in drainage systems (RWAT). Results from the four scenarios showed the following: estimation of scenarios one and four encountered singular covariance matrices, and models in scenarios two and three were successfully estimated but did not yield any significant variables.

According to Donny Latiolais, cover and green manure crop have not been used much in the southeastern region of Louisiana. Since most of the respondents were from that region, GMANU was left out of the second set of models for the group of practices targeting erosion reduction. Estimations in scenarios two and three were successful but did not yield any significant variables. Estimation of the model in scenario four yielded the largest log likelihood value. The β coefficient associated with YIELD was significant at the 10 percent level, as shown in Table 4.14. The value of the discrete change suggested that an increase of 100 lbs of milk in the productivity per cow would increase the probability to adopt all five practices simultaneously by 0.2 percent.

Two sets of models were considered for the group of practices for sediment control purposes labeled category II in Table 4.13. The first set of models included all four practices: filter strips (FILTS), sediment basin (SEDB), riparian forest buffers (RIFOBU), and streambank and shoreline protection (STRMP). Estimations of the models in scenarios one and four resulted in singular covariance matrices. Models in scenarios two and three were successfully estimated.

Table 4.13. Different Scenarios Considered in the Multivariate Probit Analysis.

Categories	System of Equations	Variables From Probit Analysis (17-21) Variables	PCA $(\lambda = 1)$ 12 Variables	PCA $(\lambda = 1)$ and significant variables from Probit Model	Variables From Probit Model significant at least at 50%
I	GMANU-CAREA-FILDB-GRSW-HVUSE-RWAT	Singular V matrix	Lu = -383.3351 No significant variables	Lu = -379.9837 No significant variables	Singular V matrix
	CAREA-FILDB-GRSW-HVUSE-RWAT	Singular V matrix	Lu = -318.0332 No significant variables	Lu = -314.6499 No significant variables	Lu = -300.2012 [1]
II	FILTS-SEDB-RIFOBU-STRMP	Singular V matrix	Constrained model [1] Lu = - 234.7103	Full model [2] Lu = -220.8550 No significant variables LR = 27.7 > $X^2(9)$=16.92	Singular V matrix
	FILTS-RIFOBU-STRMP	Singular V matrix	Singular V matrix	Singular V matrix	Singular V matrix
III	ROOFR-WSTF-WSTL-WSTUT	Singular V matrix	Lu = -231.2290 No significant variables	Singular V matrix	Singular V matrix
	WSTF-WSTLG-WSTUT	Full model Lu = -144.4487 No significant variables	Lu = -160.6722	Lu = -146.8954 No significant variables	Constrained model [1] Lu = -146.4850 LR = 4.07 < X^2(26) = 38.88
IV	PGRAZ-FENCE-TROUGH	Singular V matrix	Constrained model Lr = -160.1843	Full model [1] Lu = -147.9179 LR = 24.53>X^2(5)=11.07	Singular V matrix

[1] : Models with results presented in Table 4.14; and [2] : "Best" model based on the LR test.

Table 4.14. Results of the Multivariate Probit Analysis.

Variables	CAREA-FILDB-GRSW-HVUSE-RWAT						FITLS-SEDB-RIFOBU-STRMP				
	B1	B2	B3	B4	B5	Δ	B1	B2	B3	B4	Δ
ONE	-3.1258	-2.7053	-2.9210	-0.7861	-0.1783		-3.0243	-1.6338	-2.6722	-1.5575	
COWS	0.0031	0.0063	0.0010		0.0022		0.0040	0.0045	0.0005	-0.0024	
YIELD	0.0145	0.0167	0.0192*	0.0052		0.0024	0.0166*	0.0040	0.0074	0.0058	0.0017
STRM1	0.2744		-0.5220	0.3197			-0.2613	-0.0272	0.2306	0.7359	
HEL	0.1032		0.2930		-0.2126		0.1349	-0.0296	0.0477	-0.0169	
BSTR			0.1799		0.3247		0.1625	0.7887*	0.2538	0.7724	0.1371
LAND	-0.1649		0.4783	-0.2561	-0.4146						
NWTH	-0.3566	-0.3525		-0.3460	0.4808						
DEBT				-0.2276							
AGE	-0.0106				-0.0171		-0.0054	-0.0181	-0.0032	-0.0109	
OFFF		0.4934	-0.3253								
TOVR		0.3326									
DHIA	-0.5225	-0.2516	-0.6928		-0.5705		-0.4893	-0.2669	-0.5472	-0.2307	
COOP					0.5845		-0.0199	0.2604	0.1949	0.3997	
LCES	0.1113	0.2119	0.0965		0.0495		0.1100	0.0862	0.1569	0.0530	
SEM		0.0163	0.0578				0.0469	-0.0044	-0.0060	0.0312	
SCAP5	0.0915						-0.0371	0.1162	-0.0602	0.1795	
SCAP2	0.2942	-0.1715	-0.2186	0.2940	0.2275		-0.1580	0.1937	0.2958	-0.1048	
RISK		0.3630	0.4279	0.1589	0.2205						
ENV		0.1328	-0.2212	-0.1721							
SCAP4		-0.5845									
R(01, 02)			0.7252**						0.1990		
R(01, 03)			0.6705**						0.6972**		
R(01, 04)			0.5817**						0.3558		
R(01, 05)			0.3424						0.4675**		
R(02, 03)			0.7905**						0.6646**		
R(02, 04)			0.7226**						0.7921**		
R(02, 05)			0.5798**								
R(03, 04)			0.7477**								
R(03, 05)			0.3061								
R(04, 05)			0.5078*								
Log likelihood			Lu = -318.0332 [(a)]						Lu = -234.7103 [(b)]		

B_i : Coefficients for equation **i**; Δ : Discrete changes in the probability that all considered practices are adopted with respect to the changes in the specific variables; ** : Values significant at 5%; * : Values significant at 10%; [(a)] : Model derived from the specified equations in the probit analysis and includes variables at least 50% level of significance; and [(b)] : Current model derived from the PCA $(\lambda = 1)$.

Table 4.14. (Continued).

Variables	WSTF-WSTLG-WSTUT				PGRAZ-FENCE-TROUGH			
	B1	B2	B3	Δ	B1	B2	B3	Δ
ONE	-1.0669	0.5072	-0.8557		1.1944	0.4757	-2.0867	
COWS	0.0027				-0.0003	0.0009	-0.0010	
YIELD	0.0127				-0.0013	0.0064	0.0085	
STRM1	0.3804	0.5227			0.4454	0.0543	0.1578	
HEL	0.1411		0.2534*	0.0428	-0.00002	-0.0174	0.0857	
BSTR	0.3267	-0.3918			-0.0056	0.0163	0.1520	
LAND	-0.2851	-0.3046			-1.3841*			-0.0024
PASTU					1.2301**			0.3916
OCROP			0.3037					
AGE	-0.0225		-0.0117		-0.0186	-0.0344	-0.0015	
OFFF	0.7420		-0.7591*	-0.0202				
EDUC		0.4124						
CSP					-0.6355			
DHIA					-0.4160	-0.3336	-0.1048	
COOP	-0.6227				-0.2063	0.2773	0.5754	
LCES	0.1179		0.1591		0.3823**	0.0328	0.0098	0.0480
SEM	0.0407	0.0671			-0.0049	0.0101	0.2426**	0.0308
NRCSP			0.7187					
SCAP5		-0.1505			0.0172	0.1874	0.0079	
SCAP2		0.1582			0.1440	0.0746	0.0734	
RISK	0.7132	0.2826	0.6326			0.4476	0.3367	
SCAP4			0.3370					
R (01, 02)	0.7211				0.6219*			
R (01, 03)	0.8063				0.8926**			
R (02, 03)	0.7999				0.8054**			
Lu	-144.4487 [(a)]				-147.9179 [(c)]			
Lr	-146.4850 [(b)]				-160.1843 [(d)]			
LR	LR = 4.07 and $X^2(26) = 38.88$				LR = 24.53 and $X^2(5) = 11.07$			

B_i : Coefficients for equation **i**;
Δ : Discrete changes in the probability that all considered practices are adopted with respect to the changes in the specific variables;
** : Values significant at 5%;
* : Values significant at 10%;
(a) : Full model with 17 to 20 variables in each equation specified in the probit analysis;
(b) : Current model constrained from the full model and includes variables with at least 50% level of significance;
(c) : Current model as full model with 12 to 16 variables in each equation specified from the PCA $(\lambda = 1)$ and significant variables in the probit analysis; and
(d) : Constrained model specified from PCA $(\lambda = 1)$.

Since the model in scenario two was nested within that of scenario three, the likelihood ratio test was conducted to select the appropriate model. The LR value of 27.7 was smaller than the χ^2 critical value; therefore, the constrained model in scenario two was selected. Cow productivity and business structured as a corporation significantly influenced the adoption of all four practices. An increase of 100 lbs of milk in the productivity per cow as well as a dairy farm structured as corporation would increase the probability of adopting all four practices simultaneously by 0.2 percent and 14 percent, respectively. The second set of models included three practices. All four estimations associated with the second model resulted in singular covariance matrices.

4.2.5.2. Wastewater and Runoff Management Practices

Two different sets of models were considered for the group of practices targeting facility wastewater and runoff management. The first set of models included all practices in the group: roof runoff management (ROOFR), waste storage facility (WSTF), waste treatment lagoon (WSTL), and waste utilization (WSTUT). Estimation of the model in scenario two was successful, but did not yield any significant variables. Estimation of the other three scenarios resulted in singular covariance matrices. Roof runoff management was left out of the second set of models, allowing for the examination of the adoption of the three waste management practices simultaneously. The models in scenario one and four are nested. Therefore, the LR test was performed to select the appropriate model. Since the LR statistical value of 4.07 was relatively smaller than the relevant critical value, the constrained model in scenario four was selected. The higher percentage of farm land classified as "highly erodible" and the holding of an off-farm job affected the adoption of the three waste management practices simultaneously. A one unit increase in the percentage of land classified as "highly erodible" would increase the joint adoption of the three waste management practices by 4 percent, and holding an off-farm job would reduce the probability by 2 percent, holding other variables constant.

4.2.5.3. Grazing Management

Estimation of the multivariate probit model for the three grazing management practices exhibit the following results: scenarios one and four resulted in singular matrices. The LR test was performed to select the appropriate model between the two nested models in scenarios two and three. The LR statistical value of 24.53 was relatively large compared to the relevant critical value. Therefore, the full model in scenario three was selected. Four variables were found statistically significant at the 5 and 10 percent levels of significance and included LAND, PASTU, LCES, and SEM. Each of the variables were associated with similar signs as in the univariate probit analysis. A one unit increase in the percentage of land owned would decrease the probability of adopting all three practices by 0.2 percent. The dairy being a pasture-based operation, one additional meeting with LCES personnel, and attendance at one additional seminar that dealt with dairy industry issues would raise the probability of adopting all grazing management practices by 39 , 5 , and 3 percent, respectively.

In summary, the adoption of BMPs by the dairy producer respondents to the survey has been influenced by the selected variables included in this study. Results of the probit analysis showed the increased effects of farm size, milk productivity per cow, frequency of meetings with LCES, and risk aversion. DHIA has consistently been associated with a negative sign. Results of the bivariate and multivariate probit analyses showed fewer variables which significantly affected the simultaneous adoption of the practices under consideration.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1. Summary

Water quality assessments in the U.S. have shown largely improved surface water quality since the enactment of the Clean Water Act. Even so, efforts to reduce water pollution continue. These efforts aim to decrease discharges from identifiable sources of water pollution and the increased contribution of diffused discharges from nonpoint sources. The traditional view of the agricultural community as a good steward of the environment has been challenged by increasing concerns about the complex relationship between agricultural production activities and environmental quality. Along with its positive contribution of providing a wide range of products to satisfy human needs, agriculture has also been blamed for contributing to environmental problems. The significant role of agriculture as a major source of water pollution has been pointed out.

Recent environmental policy has focused on reducing water pollution produced by agriculture. Different programs have been undertaken at the Federal and State levels to address agricultural point and nonpoint sources of pollution, and agricultural producers are encouraged to voluntarily implement site specific management practices known as best management practices (BMPs). These practices consist of conservation methods designed to reduce the delivery and transport of agriculturally derived pollutants such as sediment, nutrients, pesticides, salt and pathogens to surface and ground waters.

Louisiana is far from being a major U.S. milk producer. However, the dairy industry represents one of the most important animal agricultural industries in the state. Similar to other agricultural production activities, the need to adopt specific practices to improve water quality has become greater in the dairy industry as dairy farms in the Florida parishes have been targeted in recent years as polluters of waterways.

This study investigated the adoption of 21 BMPs aimed at reducing the impact of dairy farming on Louisiana's environment. Specific objectives of the study were to: examine the current efforts to contain water quality degradation, including regulatory measures, research and educational programs on environmental issues as they relate to Louisiana dairy industry; review the literature on technology adoption in the agricultural sector; assess the extent of current adoption of BMPs in the Louisiana dairy industry; determine the effects of demographic, socioeconomic and farm characteristics on producers' decisions to adopt specific BMPs; and make policy recommendations based on the empirical results.

Federal and state actions aiming at the improvement of national water quality have been continual over the years. Current programs include the pursuit of existing long-term programs initiated over fifty years ago as well as recent programs established to address specific issues. The protection, conservation and restoration of natural resources in Louisiana has involved the Natural Resources and Conservation Service (NRCS) through local soil and conservation districts, conservation development areas, landowners and partners and volunteers. Current conservation programs in Louisiana include but are not limited to: the Environmental Quality Incentives Program (EQIP), which assists eligible farmers and ranchers in complying with federal, state and tribal environmental laws through cost-sharing to implement BMPs; the Louisiana Grazing Lands Conservation Initiative (GLCI), which provides financial and technical assistance to owners and managers of pastureland, rangeland, grazed woodlands, and potentially grazed cropland, and promotes voluntary adoption of prescribed grazing practices by livestock producers; and the Conservation Reserve Program (CRP), which assists producers in retiring highly erodible and environmentally sensitive croplands for 10 to 15 years by paying producers an annual "rental fee" upon entering the program.

The study of technology adoption has retained researchers' interests over the years since Griliches' exploration of the wide differences in the rate of adoption of hybrid seed corn in 1957. Selected literature of relevance to this study were reviewed to provide insights of previous findings regarding agricultural producers' adoption of technology. Technologies ranged from those that increase production efficiency to those whose sole purpose is to reduce environmental damages associated with production activities. These studies investigated the likely determinants of agricultural producers' decisions to adopt a specific technology and used different theoretical models of adoption. Studies on environmental attitude have shown the wide-spread use of the New Environmental Paradigm (NEP) scale, developed by Dunlap *et al.* in 1978, and revised in 2000, as a measure of environmental attitude.

A mail survey of the population of dairy producers (428), designed according to Dillman's method of surveying, was conducted in Summer, 2001, to provide data for the analysis. It included a first mailing, followed by a postcard reminder, and a second mailing to non-respondents. One hundred and thirty one surveys were returned with 124 completed, achieving an effective rate of return of 29 percent.

The sample was comprised mostly of pasture-based operations located in the southeastern region of Louisiana, specifically in St. Helena, Tangipahoa and Washington parishes. Ninety percent of the farms were producing at least at the state average milk production per cow of 12,155 pounds in 2000. The survey respondents were mostly male producers, between 40 and 59 years old, with a high school diploma or a bachelor's degree. A large number of respondents were not aware of the Coastal Nonpoint Control Program, nor the effort to control water pollution through the Clean Water Act. Producers who had heard about BMPs for dairy had received the information primarily from the LCES, government agencies such as NRCS, and farm organizations such as the Farm Bureau.

Elicitation of dairy producers' attitudes toward the environment was conducted using the NEP scale developed by Dunlap *et al.* in 2000. Results showed an average score of 3.22, suggesting a tendency of dairy producers to hold, on average, a neutral attitude regarding the issues stated in the 15 items of the NEP scale.

Different rates of adoption were found for each BMP. Non-adoption was due mainly to a need for more information or the real or perceived non applicability of the specific practice to the farm. The group of practices targeting erosion and sediment control had the lowest rates of adoption, varying from 28 percent (for streambank and shoreline protection) to 48 percent (for field borders), except for conservation tillage, which was adopted by 77 percent of the respondents. The low rates might be due to producers' adoption of BMPs according to their primary activities. The adoption of practices related to erosion and sediment reduction could be secondary in the eyes of the dairy producers. Practices aiming at the management of facility wastewater recorded the highest rates of adoption among all BMPs. The adoption rates vary from 70 percent (for waste storage facility) to 83 percent (for waste management system). These practices have been emphasized greatly by NRCS in recent years. The adoption of nutrient and pesticide management were 69 and 62 percent, respectively. Survey results suggest that about 10 percent of the producers had not heard about these two BMPs, 11 percent of the respondents considered nutrient management not applicable to their farms and 23 percent thought the same regarding pesticide management. The three grazing management practices had high rates of adoption: 80 percent for fencing; 72 percent for grazing management; and 70 percent for trough or tank. The pasture-based operation type of most respondents' dairies explains these rates of adoption of grazing management practices.

However, these adoption rates, based on the total respondents, might be understated given the relatively high rates of "non applicability" responses. The true adoption rates regarding the practices targeting erosion and sediment control might be higher than those actually provided when accounting only for dairy farms that should apply the BMP. This is consistent with the site specific characteristic of BMPs. The adoption rate will go up if the denominator accounts for a smaller number of producers that should adopt the BMP. On the other hand, as Donny Latiolais suggested, there might be producers who already implemented the practice but failed to recognize the BMP despite the short glossary provided in the survey. In such a case, the numerator of the ratio, accounting for the total number of producers adopting the BMP would be higher, and so would be the percentage of adoption.

A second limitation in interpreting these numbers as representative is that the average milk yield of the surveyed farmers, 14,984 pounds, was higher than the average Louisiana dairy farm milk yield, 12,155 pounds in 2000. Since higher yielding producers were generally the more extensive adopters, these adoption rates may be overstated. However, the differences may not be great, given the relatively small marginal effects of YIELD on the probability to adopt, ranging from 0.02 to 0.08 percent for each additional 100 pounds in milk production per cow.

Producers' decisions regarding whether to adopt a specific BMP were investigated through probit analysis. The simultaneous adoption of two or more BMPs was examined using bivariate and multivariate probit models, assuming contemporaneous errors between adoption equations. Thirty two variables were hypothesized as relevant in determining dairy producers' decisions to adopt BMPs, and descriptive statistics of these variables were provided.

Collinearity diagnostics revealed four variables were strongly correlated. Thus, variables accounting for social relationships with neighboring farmers (SCAP1) and other agricultural businesses (SCAP3) were assessed as less important in the decision process and were excluded from the set of explanatory variables to reduce the collinearity problem. The conduct of principal component analysis (PCA) allowed for reducing the number of variables from 30 to 17 (with $\lambda = 0.7$) and 12 (with $\lambda = 1$) needed for the multivariate probit analysis.

Four different probit models were run for each BMP: a base model with 30 variables; a second model with the 17 variables retained from the PCA procedure; a third model as an extension of model two, with extra variables from the base model that were significant at the 10 percent level; and a fourth model with variables from the base model that were significant at the 50 percent level. All Lagrange multiplier statistic values had large p-values, suggesting homoskedastic error terms associated with each adoption equation. The values of McFadden and Estrella R^2 statistics were relatively low, about 0.20, except for the waste management system (0.50) and prescribed grazing (0.40) equations. Estimates of the Akaike Information Criterion (AIC) and the Schwartz Criterion (SC), as well as the conduct of the likelihood ratio test allowed for selection of the best model to be considered in the multivariate analysis. The marginal effects of continuous explanatory variables were assessed at mean values of all variables as well as at selected values of the dummy variables. Discrete changes in the predicted probabilities were estimated as an alternative to marginal effects in the case of dummy variables.

Results from the probit models suggest that farm size (COWS), milk productivity (YIELD), frequency of meetings with LCES personnel (LCES), and risk aversion (RISK) were associated with significant increases in the adoption of 5 to 8 specific BMPs. Nine variables were found significantly associated with increased adoption of 1 to 3 specific BMPs. These variables include: having a stream running through the farm land (STRM1), percentage of land classified as "highly erodible" (HEL), business structured as a corporation (BSTR), dairy farm net worth (NWTH), the holding of an off-farm job (OFFF), farmer's educational attainment (EDUC), having a family member planning to take over the dairy operation upon the producer's retirement (TOVR), membership in a milk cooperative (COOP), and good relationships with lending institutions (SCAP2).

Variable AGE frequently had a negative sign, which was as expected. Older producers would be expected to have shorter planning horizons and would be less willing to alter their management strategies. The consistent negative association between membership in DHIA and BMP adoption was not as expected. In this study, better record keepers, likely to be the more progressive farmers, were hypothesized to be more willing to adopt conservation practices. The negative correlation could be because of DHIA targeting dairy farm productivity and ensuring higher profit through highly monitored business management. Conservation practices, on the other hand, primarily target an overall improvement of the environment, which may ensure long term financial viability, but may not result in greater short-run profit.

Dairy producers most likely to adopt BMPs were more likely to be operating larger farms with greater milk productivity per cow. These producers were also more highly educated and risk averse. The significant influence of meetings with LCES personnel suggests the importance of information dissemination in inducing adoption of BMPs, and the effectiveness of LCES at influencing adoption.

The adoption of two BMPs simultaneously was examined using bivariate probit analysis, based on the selected models from the probit analysis of each BMP. The group of practices aiming at erosion and sediment control was divided into two subcategories according to whether they target primarily erosion reduction or sediment control. Thirty-eight bivariate probit models were analyzed in total: 21 for the seven practices in the subgroup of practices targeting the reduction of soil erosion; six for the group of practices aiming at sediment control; seven for the group of practices dealing with facility and wastewater and runoff management; one for nutrient and pesticide management; and three for the grazing management practices.

Thirty-two of the rho coefficients were found statistically significant at the 5 or 10 percent levels of significance, suggesting simultaneity in the adoption of BMPs. Conditional marginal effects associated with the bivariate model were provided. Models associated with the group of practices targeting erosion and sediment control tended to heavily predict the adoption of neither practice under consideration, probably due to the low rate of adoption of most practices in the group.

Compared with the univariate probit analyses, fewer variables were found to significantly influence the simultaneous adoption of two practices. The holding of an off-farm job, plans for a family member to take over the dairy operation upon the farmer's retirement, frequency of meetings with LCES personnel and good relationships with non-farmer neighbors were associated with greater adoption of field borders given that grassed waterways had been adopted. Larger percentages of farm land classified as "highly erodible" and a good relationship with non-farmer neighbors would increase the adoption of grassed waterways provided that field borders had been established.

The holding of an off-farm job was the only variable that had a significant positive effect on the implementation of both a waste storage facility and waste utilization practices. Off-farm income allow producers to overcome the capital constraint associated with the implementation of somewhat capital intensive practices such as the construction of pound for waste storage.

Membership in DHIA would reduce the implementation of nutrient management if producers had adopted pesticide management. Having a stream and/or river running through the farm would increase the adoption of pesticide management by producers with a nutrient management plan. Meeting with LCES personnel would increase the establishment of a prescribed grazing plan if dairy farmers had their land fenced, but a larger percentage of land owned to total acres of land included in the operation would reduce the adoption.

The simultaneous adoption of larger sets of three to six BMPs in each group of practices was investigated. Four different scenarios were examined regarding the variables to be included in the system of 3 to 6 equations in the multivariate probit analysis. Models in the first scenario included variables from the selected probit models. Models in scenario two included the 12 variables obtained from the PCA $(\lambda = 1)$ in each of the equations. Models in scenario three, as extensions of the models in scenario two, included some extra variables from the probit models that were significant at the 10 percent level. Models in scenario four included variables from the probit models that were significant at the 50 percent level of significance. Two sets of models were considered for each group of practices. Discrete changes in the probability of adopting all practices under consideration were estimated as alternatives to marginal effects. Fewer variables were significant as more equations were considered in the multivariate probit analysis. Dairy farms with higher milk productivity were likely to simultaneously implement the five practices targeting erosion reduction including critical area planting, field borders, grassed waterways, heavy use area protection and regulating water in a drainage system. Milk productivity and business structured as a corporation would enhance the adoption of four sediment control practices such as filter strips, sediment basin, riparian forest buffer and streambank and shoreline protection. A higher percentage of farmland classified as "highly erodible" and the holding of an off-farm job likely increased the adoption of waste facilities, a lagoon and proper waste utilization. Pasture-based operations and diversification of farming activities would enhance producers' implementation of the three grazing management practices.

5.2. Conclusions and Recommendations

This study showed that the adoption of BMPs by Louisiana dairy producers was influenced by factors such as farm characteristics, operator characteristics, institutions related to the dairy operation, and producers attitude. Results of the analysis emphasized:

- The positive influence of farm size on the adoption of BMPs that are not particularly capital-intensive in nature such as conservation tillage, critical area planting, field borders and filter strips. Such practices are unlikely to require substantial initial capital investment and economies associated with spreading associated fixed costs over greater output are not likely to be substantial in most cases. The rationale for such results would be the possibility of larger farms appropriating the learning costs as fixed expenses, as suggested by Feder *et al.* (1985);
- The effect of milk productivity per cow on the increased adoption of BMPs such as cover and green manure crops, establishment of field borders, filter strips, grassed waterways, waste storage facility, and nutrient management. Higher milk productivity is indicative of a well-managed farm. Although BMPs do not necessarily affect milk productivity in the short-run, better managers are likely to adopt practices that ensure the long-run viability of their operations. In the case of the waste storage facility, substantial initial investment is likely to be required. More productive farms will more likely be better able to bear the fixed adoption costs associated with such a facility;

- The increased effect of frequent meetings with LCES personnel on the adoption of eight BMPs including conservation tillage, the establishment of field borders, grassed waterways, riparian forest buffers, the construction of a waste storage facility, proper utilization of wastes, a nutrient management plan, and prescribed grazing. These results underscore the importance of information dissemination in inducing adoption and the effectiveness of LCES in providing BMP information to producers;
- The influence of producer's risk aversion on the adoption of six of the more capital intensive BMPs. These practices included the establishment of grassed waterways, the construction of a sediment basin, streambank and shoreline protection, waste storage facilities, proper utilization of waste and fencing. Adoption of such BMPs helps to ensure long-run economic viability of the land and avoidance of the risk associated with decreased productivity resulting from unusually heavy rainfall events;
- The consistent negative effect of membership in DHIA on the adoption of nine somewhat capital intensive BMPs including critical area planting, filter strips, grassed waterways, regulating water in a drainage system, riparian forest buffers, sediment basins, streambank and shoreline protection, and waste storage facility. DHIA allows for enhancing dairy operation productivity and ensuring higher profit through an extensive record keeping system. The negative effect of DHIA suggests that the adoption of BMPs might not be consistent with the goals of producers who place greater weight on the profit-maximization goal, as opposed to other goals such as conserving and maintaining land. These producers may require greater economic incentives to induce adoption, offered through extended cost-sharing programs or programs that provide financial assistance for maintenance of BMPs;

- The lower probability that older producers had adopted BMPs that required substantial initial capital investments such as sediment basins, waste storage facilities, and fencing. Such investments are unlikely to be made by producers with short planning horizons since the producer cannot benefit from the full stream of benefits, but must absorb the full costs;
- The result that producers with highly erodible land or streams running through their farms, land characteristics that place a farm at particular risk of polluting water, were more likely to adopt several practices. Grassed waterways and waste utilization were used more by producers with highly erodible land. These are BMPs that can address runoff concerns if utilized properly. Streambank and shoreline protection was utilized, not surprisingly, by those who had streams running through their land. These results likely show the effectiveness of educational programs at targeting high risk polluters for adoption, and the benefits such producers recognize from adoption; and
- The greater likelihood of more highly educated producers to adopt streambank and shoreline protection, waste management systems, waste treatment lagoons and pesticide management. Higher educational attainment allows farmers not only greater access to information, but also recognition of the benefits and costs of alternative management strategies such as adopting BMPs. More educated producers may have more ability to adjust to changes.

The relatively high rates of adoption of facility wastewater management practices as well as those related to grazing management indicate that most dairy producers have established these practices. However, the overall findings suggest the need to address the following points:

- The lack of knowledge among dairy producers about BMPs. This is reflected by the large number of producers unaware of legislation and efforts to control nonpoint sources of water pollution, as well as the high rates of respondents answering "need more information" and "have not heard about it" as reasons for not adopting a BMP;
- The low rate of producers having a dairy farm plan with NRCS; and
- The need of expanded economic incentives to induce the adoption of producers who find a BMP too expensive to adopt, or are short-run profit maximizers.

The lack of information can be addressed through intensive educational programs to inform producers about BMPs such as the Louisiana Master Farmer Program. This program, co-sponsored by the LSU Agricultural Center and other groups, puts primary emphasis on educating Louisiana farmers about BMPs in a three-year program of study. The statewide educational program intends to cover the 12 watersheds in Louisiana over the next five years. Along with the educational program, it is also important to encourage dairy producers to establish a dairy farm plan with NRCS, which would allow for specifying the BMPs applicable to the dairy farm.

The need of economic incentives can be addressed through the technical and financial assistance promoted by EQIP. EQIP targets primarily (60 percent) livestock operations and supplies up to a 75 percent cost-share (90 percent for beginning farmers and ranchers) for implementing conservation practices. This program increases the profitability associated with BMPs, thereby inducing producers who place greater emphasis on the profit-maximization goal to adopt.

Lastly, the conduct of programs that assist producers in maintaining established BMPs would be necessary to ensure sustained improvement in the environment. Indeed, the recurrent expenses associated with the operation and maintenance of established BMPs could be costly to the farm operation. The Conservation Security Program (CSP), established under the 2002 Farm Bill, constitutes a national incentive payment program to assist agricultural producers in adopting and maintaining new conservation measures related to the management of land. Provisions list management practices as including but not limited to nutrient management, integrated pest management, grazing management, controlled rotational grazing, and soil conservation and residue management. Unfortunately, the program does not cover already established conservation practices. However, it might be a motivating factor for current non-adopters of BMPs for targeting erosion and sediment control.

The findings of this study pointed out, among others things, the importance of economic incentives in producers' decisions to adopt. However, this study did not provide insights regarding the extent of such incentives to induce BMP adoption nor the likely profitability of BMPs. Therefore, a thorough investigation of producers' willingness to adopt BMPs provided that economic incentives are available would allow for ascertaining the likely positive association between BMP adoption and economic incentives. Given that few estimates are available as to the costs associated with BMP adoption, further research may also examine the true profitability of a BMP to a farm and provide agricultural producers a better understanding of how BMPs impact not only the environment but also the economic viability of their operation.

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APPENDIX A

SELECTED STATISTICS ON LIVESTOCK AND MILK PRODUCTION IN LOUISIANA

Table A1. Cash Receipts from Farm Marketing in Louisiana: Livestock and Products.

(Thousand Dollars)

Products	1997	1998	1999	2000
Aquaculture	41,692	37,683	43,449	44,432
Cattle & Calves	143,975	153,810	152,543	193,382
Dairy Products	111,397	119,556	113,937	96,188
Poultry / Eggs	302,943	281,471	276,823	281,132
Hogs	6,972	4,339	2,267	2,878
Sheep and Lambs	479	133	(1)	(1)
Other Livestock & Products	34,196	34,261	32,929	35,262

(1): Data included in other Livestock & Products

Source: *2000 Louisiana Agricultural Statistics*. Louisiana State University Agricultural Center. Department of Agricultural Economics and Agribusiness. A.E.A. Information Series No. 195. September 2001.

Table A2. Selected Statistics on Milk Production in the U.S. and Louisiana: 1981 to 2000.

Years		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Farms with Milk Cows (1)	U.S.	320	308	298	282	269	249	228	216	203	193
	LA	4	3.8	3.7	3.2	3.1	3	2.8	2.5	2.3	2.1
	%	1.25	1.23	1.24	1.13	1.15	1.2	1.23	1.16	1.13	1.09
Milk Produced (2)	U.S.	133	136	140	135	143	143	143	145	144	148
	LA	0.99	0.97	0.95	0.89	0.91	0.89	0.88	0.93	0.95	0.94
	%	0.74	0.72	0.68	0.66	0.64	0.62	0.62	0.64	0.66	0.64
Production/ Cow(3)	U.S.	12.2	12.3	12.6	12.4	13	13.3	13.8	14.2	14.3	14.8
	LA	9.3	9.6	9.4	9.2	9.9	10	10.4	10.7	11	11.6
	%	76.2	78	74.6	74.2	76.2	75.2	75.4	75.4	76.9	78.4
Income (4)	U.S.	-	-	-	-	18.1	-	-	17.7	19.4	20.2
	LA	0.15	0.14	0.14	0.13	0.13	0.12	0.13	0.13	0.14	0.14
	%	-	-	-	-	0.72	-	-	0.72	0.71	0.71

Years		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Farms with Milk Cows (1)	U.S.	181	171	159	148	140	131	124	117	111	105
	LA	1.8	1.7	1.3	1.2	1.1	1	0.9	0.8	0.7	0.66
	%	0.99	0.99	0.82	0.81	0.79	0.76	0.73	0.68	0.63	0.63
Milk Produced (2)	U.S.	148	151	151	154	155	154	156	157	163	168
	LA	0.93	0.96	0.93	0.93	0.91	0.84	0.79	0.75	0.71	0.71
	%	0.63	0.64	0.62	0.6	0.59	0.55	0.51	0.48	0.44	0.42
Production/ Cow(3)	U.S.	15	15.6	15.7	16.2	16.4	16.4	16.9	17.2	17.8	18.2
	LA	11.7	12	11.8	11.7	11.9	12.1	12	11.9	11.6	12.1
	%	78	76.9	75.2	72.2	72.6	73.8	71	69.2	65.2	66.5
Income (4)	U.S.	18.1	19.8	19.3	20	19.9	22.8	21	24.3	23.4	20.8
	LA	0.12	0.14	0.13	0.13	0.12	0.13	0.11	0.12	0.11	0.096
	%	0.67	0.69	0.67	0.65	0.62	0.59	0.53	0.49	0.47	0.47

(1) : Number of farms with milk cows in 1,000 units; (2) : Total milk production in 10^9 pounds; (3) : Average Milk per cow in 10^3 pounds; (4) : Gross farm income from dairy products in $\$10^9$ (include cash receipts from sell to plants and dealers and value of milk consumed on farm).

Source: U.S. Census Bureau, Statistical Abstract of the United States.

Table A3. Selected Statistics on Dairy Farms and Milk Production in Louisiana: 1981 to 2000.

Years	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Dairy Farms (1)	995	995	966	921	887	775	763	751	727	725
Milk Cows (2)	107	102	101	97	92	89	84	87	86	81
Production/ Cow(3)	9,308	9,559	9,446	9,206	9,902	9,538	10,01	10,69	11,05	11,61
Total Production(4)	996	975	954	893	911	887	881	930	950	940
Income (5)	149.2	144.1	139.9	129.3	128.3	123.2	125.9	128.2	137.1	142.9

Years	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dairy Farms (1)	715	704	696	676	646	594	557	530	478	448
Milk Cows (2)	80	80	79	79	76	69	66	63	61	58
Production/Cow(3)	11,675	12,000	11,835	11,709	11,908	12,145	12,030	11,921	11,656	12,155
Total Production(4)	934	960	935	925	905	838	794	751	711	705
Income (5)	122.6	136.5	129.6	129.2	123.5	133.97	111.8	119.9	114.3	96.47

(1) : Units of dairy farm in Louisiana; (2): Milk cows on farms in 1,000 heads; (3): Average Milk per cow in pounds; (4) Total milk production in 1,000,000 pounds; (5) : Gross farm income from dairy products in $1,000,000 (include cash receipts from sell to plants and dealers and value of milk consumed on farm).

Sources: . Louisiana State Department of Health and Human Resources. Office of Health Services and Environmental Quality. Reports prepared by the Milk and Dairy Division (1981 through 2000);

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APPENDIX B

THE SURVEY QUESTIONAIRE AND COMPLEMENTARY DOCUMENTS

“FIRST LETTER TO PRODUCERS"

Department of Agricultural Economics andAgribusiness
101 Agricultural Administration Building
Louisiana State University
Baton Rouge, LA 70803-5604
(225) 578-3282
FAX: (225) 578-2716

June 26, 2001

Dear Dairy Producer:

As you are aware, many Americans have become concerned in recent years with the impact of agriculture on water quality. This has resulted in increased pressure for farmers to adopt management practices that are environmentally friendly, practices that are intended to reduce soil and nutrient runoff into streams. What remains unknown is the extent to which farmers have voluntarily adopted these practices. This survey seeks to determine the extent of adoption of best management practices in the dairy industry, as well as the importance of alternative goals to dairy producers.

Your participation in the survey is very important in assuring that as many producers as possible are represented in this study. The reliability of the survey results depends on the participation of producers such as you. All individual responses will be kept ***strictly confidential***. The questionnaire has an identification number for mailing purposes only. This is so that we may check your name off the mailing list when the questionnaire is returned. Your name will never be placed on the questionnaire.

We request that the person with primary decision-making authority on the farm complete the survey. Upon receipt of your completed survey, ***we will send you a check for $10.00.*** In order for you to receive the payment, you must complete and return the enclosed slip along with the completed survey.

The summarized results of the survey will be made available to all interested citizens. Two LSU graduate students in Agricultural Economics will be assisting me in analyzing the data, and will be writing their dissertations based upon the results. Thus, your participation in the study will help them complete their degree requirements.

I would be most happy to answer any questions you might have. Please write or call. The telephone number is (225) 578-2759 and my e-mail address is jgillespie@agctr.lsu.edu.

Thank you for your participation.

Sincerely,

Jeffrey M. Gillespie, Ph.D.
Associate Professor

"POSTCARD REMINDER TO PRODUCERS"

LSU AgCenter Research & Extension

July 5, 2001

Dear Dairy Producer:

Last week, a questionnaire seeking information about your dairy operation was mailed to you. The survey deals with the adoption of best management practices, dairy herd efficiency, and the importance of alternative goals.

If you have already completed and returned the survey, please accept our sincere thanks. If not, we would appreciate your returning it as soon as possible. It is important that your response be included in the study if the results are to accurately represent the production characteristics of Louisiana dairy producers.

If by some chance you did not receive the questionnaire, or it was misplaced, please call (225) 578-2759. We will send you another one today. Thank you!

Sincerely,

Jeffrey M. Gillespie, Ph.D.

"SECOND REMINDER TO PRODUCERS"

Department of Agricultural Economics andAgribusiness
101 Agricultural Administration Building
Louisiana State University
Baton Rouge, LA 70803-5604
(225) 578-3282
FAX: (225) 578-2716

July 20, 2001

Dear Dairy Producer:

About three weeks ago, I wrote to you asking for your participation in a survey on the use of conservation practices and goals of Louisiana dairy producers. As of today, we have not yet received your completed questionnaire. I am writing to you again because of the importance of each survey to the usefulness of this study. The reliability of the study results depends on the participation of producers such as you.

The information gathered in this survey will be used to assess the extent of adoption of best management practices in the dairy industry. Results will allow us to determine which practices are being used and the economic forces that affect adoption. We are also assessing the importance of each of seven producer goals with respect to dairy production. Lastly, information collected in this survey will be help us in estimating our annual costs and returns for dairy production. These estimates are useful management tools for dairy producers throughout Louisiana. The survey results will be analyzed by two graduate students in Agricultural Economics. These students' dissertations depend upon a good response rate to this study.

All individual responses will be kept ***strictly confidential***. No data on individual responses will ever be reported. The questionnaire has an identification number for mailing purposes only. This is so that we may check your name off the mailing list when the questionnaire is returned. Your name will never be placed on the questionnaire. The questionnaire should be completed by the person with primary decision-making authority on the farm.

Because of the importance of this study, ***we will send you a check for $10.00 upon receipt of the survey.*** To receive the payment, you must complete and return the enclosed slip along with the completed survey. In the event that your survey has been misplaced, a replacement is enclosed. ***If you have already responded to the survey and we haven't yet received your response, please accept our sincerest thanks.***

I would be most happy to answer any questions you might have. Please write or call. The telephone number is (225) 578-2759 and my e-mail address is jgillespie@agctr.lsu.edu.

Your cooperation is greatly appreciated.

Sincerely,

Jeffrey M. Gillespie, Ph.D.
Associate Professor

"SURVEY USED TO COLLECT THE DATA"

Use of Conservation Practices and Goals of Louisiana Dairy Producers

A SURVEY

LSU AgCenter
Research & Extension

Throughout this survey, you will be asked questions about your dairy operation and how you make production decisions. Please check the answer that best reflects your situation. **Note that all information is strictly confidential.**

Section I: Production Characteristics

1. How many cows in total do you run in your dairy herd?

   ________ (number of cows)

2. Do you raise your own replacement heifers? (Circle one)

   a) yes b) no

3. What was the average number of pounds of milk produced per cow in your herd in 2000?

   ________ lbs/cow

4. Which of the following technologies do you use in your operation? (Circle all that apply)

   a) Computer b) PC DART program c) Bovine Somatotropin (BSt) d) Artificial Insemination

5. Is your operation a pasture-based operation or a free-stall based operation? (Circle one)

   a) Pasture-Based Operation b) Free-Stall Based Operation

6. Please circle any other livestock and/or crops that you raise for sale and/or feeding (Circle all that apply).

a) Corn	e) Oats	i) Broilers	m) Hay	q) Other (Please List)
b) Cotton	f) Sugarcane	j) Sheep	n) Vegetable Production	____________
c) Wheat	g) Rice	k) Goats	o) Fruit Production	____________
d) Soybeans	h) Hogs	l) Beef Cattle	p) Forestry	____________

7. How many acres of land are included in your farm operation?

   ________ (acres)

8. Of the land you farm, how many acres do you own?

   ________ (acres)

9. How many acres of your farm are devoted to the dairy operation, including the land for crops supporting the dairy, hay, silage, pasture, barn, feedlot, etc.

   ________ (acres)

10. Do you raise corn for silage on your dairy operation? (Circle one)

    a) yes b) no

11. How many family members work on your farm?

_______ (number)

12. How many non-family member employees work on your dairy operation between 1 and 29 hours per week?

_______ (number)

13. How many non-family member employees work on your dairy operation 30 hours or more per week?

________ (number)

Section II: Goals of Dairy Producers

Dairy producers have a number of goals with respect to their operations. Below are some potential goals that you may have for your operation. Please examine each of the following goals and their definitions and then answer the questions that follow.

Maintain and Conserve Land: I want to maintain and conserve the land such that it can be preserved for future generations.

Maximize Profit*:* I want to make the most profit each year given my available resources.

Increase Farm Size*:* I want to increase the size of my operation by controlling more land and/or having newer or larger equipment or buildings**.**

Avoid Years of Loss / Low Profit*:* I want to avoid years of high losses or low profits. I want to avoid being forced out of business.

Increase Net Worth: I want to increase my material and investment accumulations.

Have Time for Other Activities*:* I want to have ample time available for activities other than farming, such as leisure or family activities.

Have Family Involved in Agriculture*:* I want my family to have the opportunity to be involved in agriculture.

Some goals are likely to be more important to you than others. Please rank the following set of goals in the order of your perceived importance. Rank the most important goal as "1", the least important goal as "7", and each of the others accordingly. Do not use a ranking more than once. In other words, do not rank two or more goals as equal.

Goal	Rank
Maintain and Conserve Land:	________
Maximize Profit:	________
Increase Farm Size:	________
Avoid Years of Loss / Low Profit	________
Increase Net Worth:	________
Have Time for Other Activities:	________
Have Family Involved in Agriculture:	________

In this section, you will be asked to compare each of the seven goals with each of the other goals. We are interested in how important each goal is when compared to the other goals. The questions will be worded similar to the one in the following example:

Example: Assume you are asked to compare two goals, **maintain and conserve land** and **increase net worth.** If the goal **maintain and conserve land** is **much more important** to you than the goal **increase net worth** then you would place an **"X"** very near the goal **maintain and conserve land**, as shown:

Maintain and conserve land ___________________I___________________ Increase net worth

On the other hand, if the goal **increase net worth** is **slightly more important** to you than the goal **maintain and conserve land** then you would place an **"X"** nearer to the goal **Increase net worth**, but closer to the middle, as shown:

Maintain and conserve land ___________________I___________________ Increase net worth

If both goals are **equally important,** you would place an **"X"** at the **middle** of the line.

Maintain and conserve land ___________________I___________________ Increase net worth

Where the "X" is marked on the line will indicate how much more important one goal is than the other.

As shown above, please indicate your preference for each of the following goals by placing an "X" **at the point on the line that best represents your preferences** for each comparison. Note that an "X" at the midpoint of a line indicates that both goals are equally important.

Maintain and conserve land _________________I_________________ Maximize profit

Maintain and conserve land _________________I_________________ Increase farm size

Maintain and conserve land _________________I_________________ Avoid years of loss / low profit

Maintain and conserve land _________________I_________________ Increase net worth

Maintain and conserve land _________________I_________________ Have time for other activities

Maintain and conserve land _________________I_________________ Have family involved in ag.

Maximize Profit _________________I_________________ Increase farm size

Maximize Profit _________________I_________________ Avoid years of loss / low profit

Maximize Profit _________________I_________________ Increase net worth

Maximize Profit _________________I_________________ Have time for other activities

Maximize Profit _________________I_________________ Have family involved in ag.

Increase farm size _________________I_________________ Avoid years of loss /low profit

Increase farm size _________________I_________________ Increase net worth

Increase farm size _________________I_________________ Have time for other activities

Increase farm size _________________I_________________ Have family involved in ag.

Avoid years of loss / low profit	________________I________________	Increase net worth
Avoid years of loss / low profit	________________I________________	Have time for other activities
Avoid years of loss / low profit	________________I________________	Have family involved in ag.
Increase net worth	________________I________________	Have time for other activities
Increase net worth	________________I________________	Have family involved in ag.
Have time for other activities	________________I________________	Have family involved in ag.

Section III: Risk Attitude and Relationship with Community

1. Relative to other investors, how would you characterize yourself? (Circle one)
   a) I tend to take on substantial levels of risk in my investment decisions.
   b) I neither seek nor avoid risk in my investment decisions.
   c) I tend to avoid risk when possible in my investment decisions.

2. With respect to your farm operation, how important are each of the following relationships with the other members of your community? (Please circle your response)

NI = not important at all **NVI** = not very important **SI** = somewhat important **VI** = very important

a) Relationship with neighboring farmers	NI	NVI	SI	VI
b) Relationship with lending institutions (i.e., banks)	NI	NVI	SI	VI
c) Relationship with other agricultural businesses	NI	NVI	SI	VI
d) Relationship with neighbors who are non-farmers	NI	NVI	SI	VI
e) Relationship with other dairy producers throughout Louisiana	NI	NVI	SI	VI
f) Relationship with regulatory agencies	NI	NVI	SI	VI

Section IV: Producer and Farm Characteristics

1. Are you male or female? (Circle one)

   a) male b) female

2. Are you married? (Circle one)

   a) yes b) no

3. Which of the following best describes your ethnic background? (Circle one)

   a) American Indian c) Black (African American) e) White (Caucasian)
   b) Asian or Pacific Islander d) Hispanic f) Other________________

4. What is your age?

________ (years)

5. What is your level of education? (Circle one)

a) Not a High School Graduate c) Technical or College Associate's Degree e) College Master's Degree
b) High School Graduate d) College Bachelor's Degree f) College Doctoral Degree

6. How many children 18 years or younger live in your home?

a) None b) 1 c) 2 d) 3 e) 4 f) 5 or more

7. Do any of your children or any other family member plan to take over your dairy operation upon your retirement?

a) yes b) no c) do not know

8. Please circle the business structure that applies to your dairy farm. (Circle one)

a) Sole Proprietorship b) Partnership c) Family Corporation d) Non-Family Corporation

9. Are you a member of a dairy (milk) cooperative? (Circle one)

a) yes b) no

10. How many years have you been operating your dairy farm? ________ (years)

11. Do you have an off-farm job? (Circle one)
a) yes b) no

12. Which of the following best describes your annual household net income? (Circle one)

a) <$20,000 d) $60,000 to $79,999 g) $120,000 to $139,999
b) $20,000 to $39,999 e) $80,000 to $99,999 h) ≥$140,000
c) $40,000 to $59,999 f) $100,000 to $119,999

13. What percentage of your annual household net income comes from your dairy operation? (Circle one)

a) 1 to 20 percent c) 41 to 60 percent e) 81 to 100 percent
b) 21 to 40 percent d) 61 to 80 percent

14. What percentage of your annual household net income comes from off-farm employment? (Circle one)
a) zero c) 21 to 40 percent e) 61 to 80 percent
b) 1 to 20 percent d) 41 to 60 percent f) 81 to 100 percent

15. Which of the following best describes your current net worth? (Circle one)

a) <$50,000 c) $100,000 to $199,999 e) $400,000 to 799,999
b) $50,000 to $99,999 d) $200,000 to $399,999 f) ≥$800,000

16. What is your debt/asset ratio? (Circle one)

a) zero b) 1 to 20 percent c) 21 to 40 percent d) 41 to 60 percent e) over 60 percent

17. On this farm, which generation does the current operator represent (including your family or your spouse's family)? (Circle one)

a) 1st b) 2nd c) 3rd d) 4th e) 5th f) 6th or more

18. In which parish is your dairy farm located? ______________________________ (the name of parish)

Section V: Best Management Practices

1. Are you aware of the Coastal Non-Point Pollution Control Program (CNPCP) as specified in the Coastal Zone Management Act? (Circle one)

   a) yes b) no

2. Are you aware of efforts to control non-point sources of water pollution through the Clean Water Act?

   a) yes b) no

3. Have you modified the management of your dairy farm as a result of this legislation? (Circle one)

   a) yes b) no c) not applicable

4. How would you rate the quality of surface water in your area? (Circle one)

   a) very good b) good c) fair d) poor e) very poor

5. What is your primary source of information about water quality problems? (Circle one)

   a) Louisiana Cooperative Extension Service
   b) Government agencies (Natural Resources Conservation Service (NRCS), and others)
   c) Farm organizations (Farm Bureau, others)
   d) Other farmers

6. Have you ever heard about BMPs for dairy operations? (Circle one)

   a) yes b) no

If yes, what is your primary source of information? (Circle one)

a) Louisiana Cooperative Extension Service
b) Government agencies (NRCS, others)
c) Farm organizations (Farm Bureau, others)
d) Media (Radio, TV, Magazines, etc.)
e) Other ______________________________

7. In your opinion, would/does the use of Best Management Practices on your dairy farm improve the quality of water leaving your land? (Circle one)

   a) yes b) no

8. Please check any of the practices that you currently implement under "yes" column. In cases where you have not implemented a BMP, please indicate your reason for non-implementation under the appropriate "no" column. Please check only one box in each row. A description of the management practices is provided following on the next page.

Management Practices	Current Adoption				
	Yes	No			
		Need More Information	High Cost of Implementation	Have Not Heard of It	Not Applicable to my Farm
Conservation Tillage Practices					
Cover and Green Manure Crop					
Critical Area Planting					
Fence					
Field Borders					
Filter Strips					
Grassed Waterway					
Heavy Use Area Protection					
Nutrient Management					
Pest Management					
Prescribed Grazing					
Regulating Water in Drainage System					
Riparian Forest Buffer					
Roof Runoff Management					
Sediment Basin					
Streambank and Shoreline Protection					
Trough or Tank					
Waste Management System					
Waste Storage Facility					
Waste Treatment Lagoon					
Waste Utilization					

Description

Conservation Tillage Practices: A system designed to manage the amount, orientation and distribution of crop and other plant residues on the soil surface year-round.

Cover and Green Manure Crop: A crop of close growing grasses, legumes or small grains grown primarily for seasonal protection and soil improvement.

Critical Area Planting: A planting of vegetation such as trees, shrubs, vines, grasses or legumes on highly erodible areas.

Fence: A constructed barrier to livestock, wildlife or people to facilitate the application of conservation practices.

Field Borders: Strips of perennial vegetation to control erosion and protect the edges of a field.

Filter Strips: Areas of vegetation planted around fields to remove wastewater sediment and nutrients from runoff.

Grassed Waterway: A channel that is shaped or graded to required dimensions and established in suitable vegetation to convey runoff from terraces, diversion or other water concentration.

Heavy Use Area Protection: Protection of heavily used areas by establishing vegetative cover.

Nutrient Management: Management of the amount, form, placement and timing of application of plant nutrients (fertilizers) for optimum forage and crop yields.

Pest Management: A pest management program consistent with crop production goals and environmental standards.

Prescribed Grazing: Controlled harvest of vegetation with grazing animals.

Regulating Water in Drainage System: To control the removal of surface runoff, primarily through the operation of water control structures.

Riparian Forest Buffer: An area of trees, shrubs and other vegetation located adjacent to watercourses or water bodies.

Roof Runoff Management: A facility for collecting, controlling and disposing of roof runoff water.

Sediment Basin: A basin to collect and store debris or sediment.

Streambank and Shoreline Protection: Use of vegetation or structures to stabilize and protect banks of streams and lakes against scour and erosion.

Trough or Tank: A trough or tank with needed devices for water control and waste disposal installed to provide drinking water for livestock.

Waste Management System: A planned system for managing liquid and solid waste including runoff from concentrated waste areas.

Waste Storage Facility: An impoundment to temporarily store manure, wastewater and contaminated runoff.

Waste Treatment Lagoon: An impoundment to biologically treat organic waste, reduce pollution and protect the environment.

Waste Utilization: Use of agricultural waste on land in an environmentally acceptable manner to provide fertility for crop forage, and to improve or maintain soil structure.

9. Have you developed and/or updated a dairy farm plan with NRCS within the last three years?

a) yes b) no

10. Of the land on your dairy farm, approximately what percentage would be classified as "highly erodible"? (Circle one)

a) 0 to 19 percent
b) 20 to 39 percent
c) 40 to 59 percent
d) 60 to 70 percent
e) 80 to 100 percent

11. Of the land on your dairy farm, approximately what percentage would you classify as "well-drained"? (Circle one)

a) 0 to 19 percent
b) 20 to 39 percent
c) 40 to 59 percent
d) 60 to 70 percent
e) 80 to 100 percent

12. How far from your dairy farm is the nearest neighboring dairy farm? (Circle one)

a) < 1 mile b) 1 to 5 miles c) > 5 miles

13. How far from your dairy farm is the nearest stream or river? (Circle one)

a) a stream / river runs through my farm
b) less than half a mile
c) between one-half mile and one mile
d) more than one mile

14. During the last year, how often did you meet with Louisiana Cooperative Extension Service personnel?

________ (number of times)

15. During the last year, how often did you meet with NRCS personnel?

________ (number of times)

16. Are you a member of the Dairy Herd Improvement Association (DHIA)? (Circle one)

a) yes b) no

17. Have you participated in any dairy cost-sharing programs while implementing a BMP? (Circle one)

a) yes b) no

18. How many seminars and/or meetings did you attend in 2000 that dealt with dairy production and/or dairy industry issues?

________ (number)

19. How many farm magazines did you subscribe to in 2000? (i.e., an annual subscription to *Farm Journal* would be considered <u>one</u> subscription.)

________ (number)

20. How many dairy-related university publications did you read in 2000? ________ (number)

Section VI: Environmental Attitude

The following are standard statements used previously by researchers that deal with the relationship between humans and the environment. For each statement, please indicate the extent to which you agree or disagree. (Circle your response)

SA = Strongly Agree **MA** = Mildly Agree **U** = Unsure **MD** = Mildly Disagree **SD** = Strongly Disagree

1. We are approaching the limit of the number of people the earth can support………….. SA MA U MD SD
2. Humans have the right to modify the natural environment to suit their needs………… SA MA U MD SD
3. When humans interfere with nature it often produces disastrous consequences ……….. SA MA U MD SD
4. Human ingenuity will insure that we do NOT make the earth unlivable……………... SA MA U MD SD
5. Humans are severely abusing the environment ………….……………………….…. . SA MA U MD SD
6. The earth has plenty of natural resources if we just learn how to develop them ……… SA MA U MD SD
7. Plants and animals have as much right as humans to exist…………………………... SA MA U MD SD
8. The balance of nature is strong enough to cope with the impacts of modern industrial nations ……..…………………….…………………………... .. SA MA U MD SD
9. Despite our special abilities, humans are still subject to the laws of nature…………. . SA MA U MD SD
10. The so-called "ecological crisis" facing humankind has been greatly exaggerated ….... SA MA U MD SD
11. The earth is like a spaceship with very limited room and resources………….. ……… SA MA U MD SD
12. Humans were meant to rule over the rest of nature ..……………………………..…. SA MA U MD SD
13. The balance of nature is very delicate and easily upset…………………….……… SA MA U MD SD
14. Humans will eventually learn enough about how nature works to be able to control it ………………………………………………………………….….…. SA MA U MD SD
15. If things continue on their present course, we will soon experience a major ecological catastrophe …………………………….……………………………. SA MA U MD SD

THANK YOU!!! PLEASE RETURN THE SURVEY IN THE ENCLOSED ENVELOPE.

APPENDIX C

COLLINEARITY DIAGNOSTICS RESULTS

Table C1. Results of the Collinearity Diagnostics - 32 Variables.

No	λ_i	η_i	PROPORTION OF VARIATION									
			ONE	COWS	YIELD	STRM1	HEL	BSTR	LAND	NWTH	DEBT	PASTU
1	21.5373	1.0000	0.000008	0.0001	0.00003	0.0002	0.0003	0.0003	0.0002	0.0004	0.0002	0.0001
2	1.6122	3.6550	0.00002	0.0029	0.00003	0.0041	0.0003	0.0005	0.0011	0.0033	0.0004	0.0006
3	1.2586	4.1368	8.39 E-7	0.0011	0.00003	0.0073	0.0015	0.0474	0.0003	0.0013	0.0001	0.00009
4	1.1660	4.2978	8.92 E-7	0.00007	0.000009	0.0959	0.0003	0.0103	0.00007	0.00008	2.37 E-9	0.000009
5	0.9206	4.8370	0.000001	0.00007	0.000003	0.0581	0.00001	0.1409	0.0002	0.0397	0.0024	0.00006
6	0.7765	5.2664	0.000004	0.0003	0.00002	0.0654	0.0011	0.1304	0.0021	0.0394	0.0006	0.00007
7	0.6822	5.6189	0.000006	0.0004	0.000001	0.0005	0.0023	0.0546	0.00001	0.0013	0.0002	0.0004
8	0.5983	5.9998	0.00003	0.0012	0.00006	0.00004	0.0006	0.2677	0.000004	0.0652	0.00004	0.00007
9	0.5596	6.2039	0.000004	0.00006	0.00004	0.0053	0.0066	0.0005	0.0062	0.1065	0.0025	0.0001
10	0.5077	6.5131	0.000003	0.0012	9.57 E-7	0.00003	0.0018	0.0039	0.0006	0.0319	0.0048	0.0004
11	0.4444	6.9619	0.00001	0.00004	0.00003	0.0033	0.0426	0.0035	0.0008	0.1023	0.0044	0.0004
12	0.4203	7.1584	0.00002	0.0011	0.0002	0.0030	0.0043	0.00003	0.0001	0.0047	0.0042	0.0011
13	0.3387	7.9738	0.000005	0.0033	0.000002	0.0234	0.0574	0.0193	0.0301	0.0461	0.0005	0.000002
14	0.3131	8.2940	4.80 E-7	0.0012	0.000009	0.0027	0.0724	0.00003	0.0003	0.00003	0.0002	0.0007
15	0.2939	8.5612	0.00001	0.0058	0.00004	0.0223	0.0035	0.0262	0.0003	0.1538	0.0029	0.0018
16	0.2423	9.4285	0.000008	0.0008	0.00001	0.0384	0.1716	0.0052	0.0684	0.0035	0.0114	0.0037
17	0.2075	10.1889	0.000005	0.0136	0.0005	0.0836	0.0009	0.0121	0.1081	0.1868	0.0245	0.0036
18	0.1877	10.7120	0.00001	0.0003	0.0002	0.2363	0.0636	0.0004	0.0042	0.0573	0.0559	0.00006
19	0.1613	11.5557	0.000008	0.0009	9.36 E-7	0.0027	0.0300	0.0212	0.1043	0.0385	0.0331	0.0210
20	0.1495	12.0044	0.0002	0.0007	0.0003	0.00004	0.3088	0.0044	0.0806	0.00002	0.0679	0.0172
21	0.1230	13.2324	0.0001	0.0074	0.0008	0.1611	0.0173	0.0012	0.0991	0.0431	0.0005	0.0004
22	0.0955	15.0210	0.00007	0.0338	0.0002	0.1059	0.0182	0.1194	0.0339	0.00001	0.3043	0.0203
23	0.0808	16.3315	0.0002	0.0666	0.0026	0.0004	0.0009	0.0200	0.1819	0.0041	0.0042	0.2331
24	0.0692	17.6377	0.00004	0.2070	0.0001	0.0232	0.0095	0.0224	0.0127	0.0013	0.0287	0.2575
25	0.0542	19.9421	0.00003	0.2688	0.0013	0.0004	0.0261	0.0300	0.0152	0.0066	0.0083	0.0054
26	0.0437	22.2073	0.0001	0.0096	0.0088	0.0146	0.0280	0.0013	0.0093	0.0079	0.1739	0.0242
27	0.0377	23.9076	0.00005	0.0133	0.0093	0.0067	0.0290	0.0223	0.00003	0.00004	0.0343	0.0439
28	0.0337	25.2770	0.0025	0.0179	0.0118	0.0012	0.0185	0.0001	0.0343	0.0006	0.0043	0.0149
29	0.0249	29.3933	0.0027	0.1533	0.0234	0.0212	0.0114	0.0010	0.1170	0.00002	0.1431	0.1542
30	0.0226	30.8627	0.0017	0.0561	0.0449	0.0002	0.0245	0.0003	0.0185	0.00001	0.0163	0.0601
31	0.0187	33.9227	0.0022	0.0028	0.1979	0.0088	0.0178	0.009	0.0005	0.0038	0.0010	0.0875
32	0.0154	37.3989	0.0007	0.1084	0.3686	0.0035	0.0260	0.0138	0.0331	0.0038	0.0537	0.0001
33	0.0033	80.4303	0.9892	0.0198	0.3290	0.0002	0.0032	0.0105	0.0368	0.0465	0.0114	0.0469

Table C1. (Continued).

No	PROPORTION OF VARIATION											
	OCROP	**PART**	**FULT**	**WDL**	**STRM2**	**AGE**	**OFFF**	**CSP**	**EDUC**	**TOVR**	**EXP**	**DHIA**
1	0.0003	0.0002	0.0001	0.00009	0.0003	0.00005	0.0003	0.0004	0.0003	0.0003	0.0002	0.0004
2	0.0071	0.0223	0.0248	0.0002	0.0128	0.00009	0.0062	0.0006	0.0194	0.0011	0.0005	0.0040
3	0.0196	0.0436	0.0102	0.00001	0.0089	0.00004	0.0201	0.0148	0.0218	0.0566	0.0004	0.0013
4	0.0212	0.0014	0.0007	0.00002	0.0158	0.000003	0.1229	0.0006	0.0550	0.0031	0.0001	0.0078
5	0.0209	0.0074	0.00006	0.00005	0.0180	0.000007	0.1113	0.0001	0.0140	0.0021	0.0010	0.0232
6	0.0510	0.0038	0.00005	0.000003	0.0088	0.00005	0.0027	0.0039	0.0188	0.1671	0.0015	0.0049
7	0.2657	0.0048	0.0001	0.0004	0.0004	3.67 E-7	0.0472	0.0153	0.0110	0.0576	0.0002	0.0146
8	0.0646	0.0338	0.0041	6.52 E-7	0.0015	0.00008	0.0209	0.0878	0.0133	0.0036	0.000009	0.0518
9	0.0208	0.0190	0.0012	2.65 E-8	0.0064	0.00009	0.0010	0.0044	0.0029	0.2459	0.0015	0.0004
10	0.0723	0.00006	0.0072	0.00001	0.0271	0.00002	0.0234	0.0068	0.0293	0.0989	0.0001	0.0035
11	0.0204	0.0099	0.00002	0.0002	0.0107	0.0001	0.2812	0.000003	0.1008	0.0415	0.00008	0.0041
12	0.0676	7.09 E-7	0.0049	0.00002	0.0631	0.0002	0.0331	0.1848	0.0452	0.0229	0.0093	0.2168
13	1.17 E-7	0.0004	0.0044	0.000005	0.0073	0.0017	0.0035	0.00007	0.0095	0.0039	0.0362	0.1313
14	0.0345	0.0204	0.0053	0.0002	0.0112	0.0002	0.0471	0.0092	0.3128	0.0009	0.0022	0.0933
15	0.0117	0.1751	0.0243	0.0010	0.0360	0.0002	0.0025	0.3569	0.0030	0.0113	0.0158	0.0185
16	0.0021	0.0389	0.0075	0.00004	0.0351	0.0002	0.00004	0.0170	0.0008	0.0002	0.0148	0.0205
17	0.0002	0.0807	0.0482	0.0010	0.0302	0.0001	0.1076	0.0128	0.0205	0.00005	0.0002	0.0607
18	0.0026	0.0628	0.0713	0.00007	0.2741	0.0007	0.0003	0.0315	0.0004	0.0016	0.0053	0.0206
19	0.0005	0.1322	0.1245	0.0006	0.0001	0.0025	0.0113	0.0742	0.0549	0.0001	0.1340	0.0002
20	0.0526	0.0139	0.0037	0.0004	0.0058	0.0003	0.0121	0.0406	0.0024	0.0244	0.0380	0.0787
21	0.00005	0.1388	0.0323	0.0039	0.2707	0.0004	0.0036	0.0047	0.0451	0.0035	0.0027	0.0035
22	0.0018	0.0158	0.0112	0.0010	0.0208	0.0016	0.0484	0.0503	0.0631	0.00007	0.1774	0.0494
23	0.0077	0.0260	0.0870	0.0693	0.145	0.00003	0.0079	0.0003	0.0031	0.0124	0.0008	0.0203
24	0.00002	0.0134	0.1427	0.0916	0.0144	0.0127	0.0042	0.0002	0.0009	0.0644	0.0234	0.0030
25	0.0261	0.0011	0.2268	0.1504	0.0030	0.0002	0.0067	0.00004	0.0072	0.0028	0.0397	0.0495
26	0.0154	0.0046	0.0033	0.1710	0.0253	0.0002	0.0002	0.0079	0.0003	1.68 E-7	0.0396	0.0560
27	0.0010	0.0130	0.0309	0.0356	0.0159	0.0128	0.0475	0.0140	0.0314	0.0060	0.0001	0.0002
28	0.0266	0.0099	0.0061	0.1954	0.0035	0.0229	0.0009	0.0021	0.0620	0.0031	0.0460	0.0030
29	0.0210	0.0067	0.0781	0.0157	0.0266	0.1182	0.00007	0.0374	0.0076	0.0596	0.154	0.0001
30	0.0319	0.0016	0.0326	0.00006	0.0024	0.0374	0.0231	0.0184	0.0032	0.000001	0.0067	0.0309
31	0.0006	0.0039	0.0036	0.0099	0.0013	0.6657	0.00001	0.0006	0.0025	0.0754	0.2280	0.0258
32	0.1235	0.0902	0.0023	0.1884	0.0023	0.0389	0.0004	0.0023	0.0291	0.0237	0.0157	0.00003
33	0.0085	0.0046	0.0005	0.0635	0.0257	0.0823	0.0023	0.0002	0.0088	0.0059	0.0040	0.0021

Table C1. (Continued).

No	PROPORTION OF VARIATION										
	COOP	**LCES**	**SEM**	**NRCSP**	**SCAP5**	**SCAP2**	**RISK**	**ENV**	**SCAP1**	**SCAP3**	**SCAP4**
1	0.0002	0.0004	0.0003	0.0004	0.0001	0.00007	0.0003	0.00005	0.00006	0.00008	0.00007
2	0.0006	0.000008	0.0201	0.0144	0.00005	0.00006	0.0045	0.0002	0.00007	0.00003	0.00004
3	0.0010	0.0004	0.0146	0.0139	0.000007	0.00004	0.0023	5.94 E-7	0.000001	0.000007	1.72 E-7
4	0.000003	0.0025	0.0022	0.0061	0.00001	1.77 E-7	0.0023	0.00005	0.00003	0.00002	0.00001
5	0.0004	0.0056	0.0112	0.0002	9.14 E-7	0.00002	0.0003	0.000005	0.000006	0.000002	0.00001
6	0.0006	0.0083	0.0064	0.0277	0.0001	0.00006	0.0020	0.00005	2.85 E-8	0.000002	0.000004
7	0.00001	0.0028	0.0079	0.1552	0.0002	0.0004	0.0003	0.00008	0.00002	6.03 E-7	0.0002
8	0.0081	0.0056	0.0009	0.0012	0.00008	0.00009	0.0051	0.0003	0.0001	0.0005	0.0001
9	0.0007	0.0524	0.1640	0.0157	0.0005	0.000001	0.0006	0.00007	0.000005	9.84 E-9	0.0004
10	0.0009	0.0002	0.0996	0.3693	0.00001	0.00003	0.0017	0.00006	0.00009	0.0004	0.000005
11	0.00002	0.1389	0.0145	0.0506	0.0002	0.0001	0.0012	0.000008	0.00006	0.0002	0.0006
12	0.0015	0.0030	0.0012	0.0034	0.0004	0.00009	0.0280	0.0001	0.00005	0.0001	0.0003
13	0.0041	0.0876	0.2216	0.0249	0.0003	0.00009	0.0220	0.00008	0.0006	0.0003	0.0010
14	0.0055	0.253	0.1181	0.0012	4.54 E-7	0.000002	0.0097	0.00003	1`.23 E-7	0.0001	0.0005
15	0.0065	0.0008	0.0200	0.0354	0.0010	0.0002	0.0172	0.0005	0.0002	0.0008	0.0006
16	0.0145	0.2342	0.00002	0.0090	0.0102	0.0048	0.0439	2.20 E-7	0.0031	0.0042	0.0018
17	0.0455	0.0020	0.0006	0.0142	0.0058	0.00002	0.1053	0.00002	0.0013	0.0035	0.0053
18	0.0021	0.0006	0.0385	0.0255	2.33 E-9	0.00002	0.2293	0.00002	0.0012	0.0022	0.0006
19	0.0846	0.0066	0.0275	0.0016	0.0020	0.0028	0.0228	0.0002	0.0003	0.0018	0.0003
20	0.0499	0.00003	0.0415	0.0017	0.0056	0.00009	0.0201	0.0015	0.0058	0.0477	0.0008
21	0.0989	0.0045	0.0444	0.0554	0.0352	0.0088	0.3276	0.0005	0.0043	0.0035	0.0090
22	0.1015	0.0283	0.0023	0.0253	0.0122	0.00001	0.0502	0.0006	0.0126	0.0152	0.0107
23	0.2470	0.0023	0.0039	0.0321	0.0167	0.00003	0.0030	0.00008	0.0006	0.0044	0.0189
24	0.0218	0.0034	0.0125	0.0027	0.0592	0.0219	0.0076	0.0007	0.0019	0.0023	0.0058
25	0.0005	0.0031	0.0203	0.0045	0.0380	0.1350	0.0064	0.0006	0.0239	0.0874	0.0129
26	0.0120	0.0255	0.0099	0.0042	0.3291	0.0614	0.0154	0.0023	0.0613	0.1117	0.0353
27	0.1323	0.0246	0.0055	0.0237	0.1545	0.0266	0.0073	0.0467	0.0069	0.0107	0.5415
28	0.1024	0.0004	0.0001	0.0120	0.0038	0.2187	0.0006	0.2861	0.0185	0.0165	0.0001
29	0.0031	0.0069	0.0255	0.0557	0.1668	0.3573	0.0283	0.0606	0.1615	0.0064	0.0004
30	0.000003	0.0192	0.0202	0.0019	0.0072	0.0436	0.0021	0.0844	0.5268	0.4383	0.0495
31	0.0011	0.0098	0.0002	0.0044	0.1002	0.0112	0.0042	0.0425	0.00003	0.0087	0.0160
32	0.0070	0.0362	0.0442	0.0002	0.0494	0.0625	0.0053	0.2307	0.1181	0.2174	0.2605
33	0.0459	0.0316	0.0006	0.0065	0.0012	0.0441	0.0232	0.2410	0.0507	0.0156	0.0269

Table C2. Results of the Collinearity Diagnostics – 30 Variables.

No	λ_i	η_i	PROPORTION OF VARIATION								
			ONE	**COWS**	**YIELD**	**STRM1**	**HEL**	**BSTR**	**LAND**	**NWTH**	**DEBT**
1	19.6841	1.0000	0.00001	0.0001299	0.00004	0.0002	0.0004	0.0003	0.0003	0.0005	0.0002
2	1.6059	3.5011	0.00002	0.0029	0.00004	0.0043	0.0004	0.0006	0.0013	0.0032	0.0005
3	1.2582	3.9553	0.000001	0.0012	0.00003	0.0070	0.0016	0.0474	0.0003	0.0013	0.0001
4	1.1638	4.1126	0.000001	0.00008	0.00001	0.0980	0.0004	0.0107	0.0001	0.00009	0.000002
5	0.9203	4.6247	0.000001	0.00007	0.000003	0.0586	0.000009	0.1411	0.0002	0.0406	0.0025
6	0.7765	5.0349	0.000004	0.0003	0.00002	0.0665	0.0012	0.1302	0.0022	0.0404	0.0007
7	0.6819	5.3728	0.000007	0.0004	0.000001	0.0005	0.0023	0.0539	0.00002	0.0013	0.0002
8	0.5935	5.7591	0.00004	0.0014	0.00008	0.000007	0.0004	0.2714	0.00004	0.0718	0.0002
9	0.5595	5.9313	0.000004	0.00006	0.00004	0.0053	0.00714	0.0007	0.0068	0.1075	0.0026
10	0.5045	6.2465	7.51 E-7	0.0011	0.000007	0.00001	0.0014	0.0017	0.0002	0.0271	0.0046
11	0.4432	6.6641	0.00001	0.00003	0.00002	0.0036	0.0467	0.0041	0.0005	0.1072	0.0051
12	0.4196	6.8492	0.00002	0.0012	0.0002	0.0028	0.0036	0.0001	0.0003	0.0076	0.0042
13	0.3361	7.6529	0.000002	0.0041	0.000003	0.0257	0.0706	0.0202	0.0265	0.0395	0.0007
14	0.3129	7.9316	2.80 E-7	0.0011	0.000009	0.0033	0.0747	0.00003	0.0002	0.0001	0.0001
15	0.2922	8.2083	0.00001	0.0053	0.00004	0.0214	0.0014	0.0306	2.28 E-8	0.1674	0.0031
16	0.2343	9.1653	0.00002	0.0025	0.000007	0.0548	0.1908	0.0168	0.0491	0.0004	0.0155
17	0.2037	9.8296	0.00002	0.0110	0.0006	0.0948	0.0126	0.0041	0.1468	0.2134	0.0608
18	0.1854	10.3048	0.00004	0.0008	0.0005	0.2318	0.1414	0.00002	0.000009	0.0323	0.0285
19	0.1609	11.0616	1.50 E-7	0.0009	0.00002	0.0056	0.0061	0.0257	0.1264	0.0406	0.0532
20	0.1284	12.3810	0.0002	0.0096	0.0004	0.1360	0.2738	0.0033	0.2676	0.0374	0.0126
21	0.1152	13.0700	0.000003	0.000003	0.0007	0.0097	0.0784	0.0106	0.0101	0.0073	0.00002
22	0.0864	15.0920	0.0002	0.0808	0.0026	0.0726	0.0058	0.0602	0.0150	0.0028	0.4526
23	0.0790	15.7871	0.0001	0.0294	0.0008	0.0033	0.0048	0.0577	0.1447	0.0008	0.0614
24	0.0686	16.9361	0.00005	0.2620	0.00003	0.0297	0.0022	0.0434	0.0148	0.0004	0.0036
25	0.0494	19.9687	0.0002	0.2236	0.0098	0.0036	0.0005	0.0080	0.0002	0.00008	0.0639
26	0.0381	22.7434	0.00006	0.0197	0.0062	0.0015	0.0161	0.0254	0.0006	0.0012	0.0710
27	0.0333	24.3175	0.0027	0.0223	0.0104	0.0026	0.0118	0.00002	0.0359	0.0009	0.0046
28	0.0259	27.5681	0.0032	0.2421	0.0210	0.0410	0.0052	0.0011	0.1045	0.0005	0.1187
29	0.0189	32.2797	0.0012	0.0022	0.1037	0.0116	0.0288	0.0074	0.0002	0.0029	0.000003
30	0.0169	34.1671	0.0033	0.0451	0.4917	0.0033	0.0043	0.0120	0.0066	0.0007	0.0172
31	0.0035	75.2049	0.9886	0.0288	0.3511	0.0008	0.0052	0.0114	0.0384	0.0429	0.0116

Table C2. (Continued).

No	PROPORTION OF VARIATION										
	PASTU	OCROP	PART	FULT	WDL	STRM2	AGE	OFFF	CSP	EDUC	TOVR
1	0.0001	0.0004	0.0003	0.0002	0.0001	0.0003	0.00005	0.0003	0.0005	0.0003	0.0004
2	0.0006	0.0077	0.0230	0.0246	0.0002	0.0136	0.0001	0.0068	0.0006	0.0190	0.0013
3	0.0001	0.0203	0.0455	0.0103	0.00001	0.0087	0.00004	0.0216	0.0153	0.0226	0.0578
4	0.00002	0.0226	0.0017	0.0008	0.00001	0.0157	0.000005	0.1253	0.0008	0.0552	0.0033
5	0.00006	0.0223	0.0077	0.00006	0.00005	0.0183	0.000008	0.1151	0.0001	0.0143	0.0022
6	0.00007	0.0540	0.0040	0.00005	0.000003	0.0089	0.00005	0.0028	0.0041	0.0191	0.1719
7	0.0004	0.2812	0.0049	0.0001	0.0004	0.0004	6.09 E-7	0.0495	0.0161	0.0111	0.0591
8	0.0002	0.0634	0.0343	0.0046	0.000001	0.0011	0.0001	0.0186	0.0903	0.0116	0.0046
9	0.0001	0.0221	0.0200	0.0013	1.14 E-7	0.0066	0.00009	0.0010	0.0043	0.0029	0.2544
10	0.0002	0.0860	0.000008	0.0068	0.00003	0.0284	0.00004	0.0223	0.0109	0.0286	0.1028
11	0.0003	0.0198	0.0107	0.00007	0.0002	0.0143	0.00008	0.296	0.0005	0.1037	0.0412
12	0.0010	0.0740	0.00003	0.0048	0.00001	0.0599	0.0002	0.0459	0.1845	0.0544	0.0228
13	0.00006	0.0001	0.0008	0.0054	0.00003	0.0078	0.0016	0.0011	0.00005	0.0157	0.0044
14	0.0006	0.0373	0.0236	0.0061	0.0002	0.0120	0.0002	0.0459	0.0121	0.3106	0.0009
15	0.0014	0.0172	0.1875	0.0223	0.0008	0.0385	0.0002	0.00137	0.3699	0.0024	0.0138
16	0.0034	0.0105	0.0477	0.0176	0.000001	0.0347	0.0002	0.0061	0.0526	0.0061	0.0020
17	0.0046	0.0015	0.0587	0.0258	0.0008	0.0475	0.00009	0.0956	0.00004	0.0119	0.0013
18	0.0013	0.0124	0.0897	0.0805	0.0001	0.2692	0.0010	0.0029	0.0145	0.0001	0.0060
19	0.0156	0.0005	0.1638	0.1383	0.0007	0.000002	0.0021	0.0154	0.0587	0.0514	0.0017
20	0.0182	0.0107	0.0829	0.0256	0.0028	0.2302	0.0004	0.0232	0.0246	0.0310	0.0020
21	0.0105	0.0017	0.0315	0.0069	0.0023	0.0427	0.0004	0.0118	0.0660	0.0359	0.0084
22	0.0819	0.0006	0.0028	0.0593	0.0013	0.0190	0.0014	0.0118	0.0183	0.0548	0.0021
23	0.1589	0.0043	0.0325	0.0438	0.0963	0.0115	0.0007	0.0119	0.0030	0.0014	0.0080
24	0.3067	0.0007	0.0194	0.1784	0.0688	0.0106	0.0119	0.0052	2.95 E-7	0.00002	0.0721
25	0.0085	0.0042	0.0019	0.1684	0.3093	0.0025	0.0014	0.00479	0.0027	0.0025	0.0005
26	0.0493	0.0005	0.0165	0.0397	0.0634	0.0052	0.0128	0.0430	0.0178	0.0313	0.0047
27	0.0146	0.0282	0.0119	0.0073	0.2033	0.0055	0.0245	0.000006	0.0066	0.0602	0.0052
28	0.1921	0.0529	0.0101	0.1186	0.0207	0.0531	0.0824	0.0001	0.0148	0.0060	0.0593
29	0.0544	0.0005	0.0062	0.0013	0.0190	0.0006	0.7589	0.0017	0.0008	0.0067	0.0734
30	0.0266	0.1329	0.0542	0.0003	0.1496	0.0030	0.0134	0.0117	0.0092	0.0245	0.0080
31	0.0483	0.0099	0.0067	0.0011	0.0594	0.0306	0.0857	0.0012	0.0005	0.0047	0.0043

Table C2. (Continued).

No	PROPORTION OF VARIATION										
	EXP	DHIA	COOP	LCES	SEM	NRCSP	SCAP5	SCAP2	RISK	ENV	SCAP4
1	0.0002	0.0005	0.0002	0.0005	0.0004	0.0004	0.0001	0.00009	0.0003	0.00005	0.0001
2	0.0006	0.0039	0.0006	0.000002	0.0203	0.0143	0.00006	0.00008	0.0047	0.0003	0.00005
3	0.0004	0.0014	0.001`0	0.0004	0.0149	0.0141	0.000008	0.00004	0.0023	3.77 E-7	1.08 E-7
4	0.0002	0.0080	0.00001	0.0027	0.0024	0.0061	0.00001	9.64 E-7	0.0025	0.00006	0.00002
5	0.0010	0.0242	0.0004	0.0056	0.0115	0.0003	8.49 E-7	0.00002	0.0003	0.000004	0.00001
6	0.0016	0.0051	0.0006	0.0083	0.0065	0.0279	0.0001	0.00006	0.0020	0.00005	0.000004
7	0.0002	0.0151	0.00001	0.0029	0.0079	0.1561	0.0002	0.0004	0.0003	0.00009	0.0002
8	0.000002	0.0550	0.0093	0.0055	0.0002	0.0025	0.00008	0.0001	0.0057	0.0004	0.0001
9	0.0016	0.0003	0.0006	0.0527	0.1674	0.0161	0.0006	0.000002	0.00057	0.00007	0.0004
10	0.00002	0.0027	0.0004	0.0008	0.1033	0.3860	0.00001	0.00002	0.0026	0.00002	0.000008
11	0.000005	0.0060	0.000002	0.1377	0.0133	0.0410	0.0002	0.0001	0.0023	0.00002	0.0007
12	0.0088	0.2295	0.0012	0.0048	0.0016	0.0045	0.0004	0.0001	0.0261	0.00008	0.0004
13	0.0370	0.1316	0.0060	0.1017	0.2272	0.0184	0.0002	0.00008	0.0229	0.00004	0.0010
14	0.0019	0.0975	0.0049	0.2615	0.1239	0.0009	7.57 E-7	0.000002	0.0090	0.00002	0.0005
15	0.0159	0.0205	0.0046	0.0084	0.0328	0.0323	0.0007	0.0003	0.0168	0.0004	0.0006
16	0.0153	0.0482	0.0155	0.1887	0.0068	0.0073	0.0086	0.0051	0.0912	0.00004	0.0012
17	0.0023	0.0414	0.0545	0.0087	0.0035	0.0231	0.0081	0.0002	0.0433	0.000004	0.0063
18	0.0032	0.0296	0.0005	0.0034	0.0212	0.0189	0.0002	0.0001	0.2558	0.000003	0.0015
19	0.1523	0.0012	0.0631	0.0057	0.0189	0.0017	0.0015	0.0030	0.0147	0.00005	0.0003
20	0.0166	0.0296	0.0023	0.0030	0.0923	0.0416	0.00006	0.0005	0.1990	0.0017	0.0003
21	0.0683	0.0304	0.2861	0.00009	0.0017	0.0100	0.0992	0.0161	0.1756	4.50 E-7	0.0129
22	0.1150	0.1719	0.0039	0.0250	0.0084	0.0500	0.0036	0.0116	0.0346	0.0008	0.0248
23	0.0080	0.0046	0.2135	0.0131	0.0004	0.0128	0.0621	0.00669	0.0007	0.0006	0.0641
24	0.0174	0.0007	0.0325	0.0079	0.0131	0.0031	0.0258	0.0101	0.0037	0.0013	0.0251
25	0.0910	0.0003	0.0010	0.0314	0.0389	0.0093	0.0275	0.1933	0.0003	0.0003	0.0166
26	0.00003	0.0059	0.1463	0.0154	0.0048	0.0228	0.3005	0.0141	0.0017	0.0340	0.4952
27	0.0559	0.0005	0.0977	0.0003	0.00005	0.0080	0.0014	0.2022	0.0024	0.3396	0.0003
28	0.1046	0.0003	0.0008	0.0152	0.0393	0.0601	0.3103	0.4588	0.0398	0.0360	0.0284
29	0.2702	0.0135	0.0011	0.0182	0.0003	0.0061	0.1181	0.0059	0.0072	0.0796	0.0336
30	0.0035	0.0200	0.0038	0.0406	0.0169	9.36 E-7	0.0302	0.0235	0.0098	0.2634	0.2522
31	0.0072	0.0007	0.0477	0.0302	7.00 E-7	0.0047	0.0001	0.0472	0.0219	0.2411	0.0330

APPENDIX D

PRINCIPAL COMPONENT ANALYSIS RESULTS

Table D. Results of the Principal Component Analysis.

No	λ_i	Difference [1]	Proportion [2]	Cumulative [3]
1	4.2253	1.4411	0.1320	0.1320
2	2.7841	0.5639	0.080	0.2190
3	2.2202	0.1744	0.0694	0.2884
4	2.0458	0.1936	0.0639	0.3524
5	1.8522	0.3188	0.0579	0.4102
6	1.5334	0.0751	0.0479	0.4582
7	1.4583	0.1891	0.0456	0.5037
8	1.2692	0.0290	0.0397	0.5434
9	1.2402	0.0943	0.0388	0.5822
10	1.1458	0.0607	0.0358	0.6180
11	1.0851	0.0288	0.0339	0.6519
12	1.0563	0.1256	0.0330	0.6849
13	0.9307	0.0506	0.0291	0.7140
14	0.8801	0.0366	0.0275	0.7415
15	0.8435	0.1081	0.0264	0.7678
16	0.7354	0.0320	0.0230	0.7908
17	0.7034	0.0316	0.0220	0.8128
18	0.6718	0.0151	0.0210	0.8338
19	0.6566	0.0510	0.0205	0.8543
20	0.6056	0.0208	0.0189	0.8732
21	0.5848	0.0937	0.0183	0.8915
22	0.4912	0.0530	0.0153	0.9068
23	0.4382	0.0305	0.0137	0.9205
24	0.4077	0.0154	0.0127	0.9333
25	0.3922	0.0406	0.0123	0.9455
26	0.3517	0.0168	0.0110	0.9565
27	0.3349	0.0659	0.0105	0.9670
28	0.2690	0.0128	0.0084	0.9754
29	0.2562	0.0221	0.0080	0.9834
30	0.2341	0.0507	0.0073	0.9907
31	0.1834	0.0697	0.0057	0.9964
32	0.1137		0.0036	1.0000

λ_i : Eigenvalues of the correlation matrix;

(1) : Difference in the consecutive eigenvalues

(2) : Proportion of the variation of the correlation matrix explained by the component; and

(3) : Cumulative proportion explained.

Table D. (Continued).

Variables	EIGENVECTORS										
	PRIN1	**PRIN2**	**PRIN3**	**PRIN4**	**PRIN5**	**PRIN6**	**PRIN7**	**PRIN8**	**PRIN9**	**PRIN10**	**PRIN11**
COWS	0.3287	0.1177	-0.2306	-0.2505	-0.1528	-0.0097	0.0055	0.0346	0.2055	-0.1651	-0.0326
UIELD	0.1821	-0.0813	-0.0007	0.3671	0.0647	-0.1822	-0.0212	-0.0281	-0.0716	0.2245	-0.1930
PASTU	-0.1189	-0.1234	-0.1100	0.1020	0.0829	0.0386	0.0094	0.3935	0.1532	0.0066	-0.3816
OCROP	0.1211	-0.0683	-0.0743	0.2826	-0.1970	-0.2299	0.0122	-0.3456	0.1051	0.2795	0.1396
LAND	-0.0864	0.2747	-0.1983	0.0822	0.0776	0.1954	0.2460	-0.0684	0.0179	-0.1471	0.2089
PART	0.2259	0.2161	-0.1353	-0.2940	-0.2030	-0.0611	-0.1342	0.0662	0.0131	0.0026	-0.1802
FULT	0.3153	0.1341	-0.2387	-0.2777	-0.1967	-0.0564	-0.0199	0.0107	0.1308	-0.0407	-0.0159
BSTR	-0.0080	0.0876	0.0537	-0.2349	-0.1556	0.1079	0.2021	-0.0338	-0.0919	0.5790	-0.2506
NWTH	0.1929	0.2357	-0.1145	0.2027	0.1158	0.0425	0.1556	0.0348	0.1356	-0.1772	-0.0047
DEBT	0.0035	-0.2345	0.0758	-0.2985	-0.0279	0.2833	0.1331	0.0809	0.0764	0.3222	0.3193
HEL	0.0596	-0.1014	-0.1565	0.1851	0.0875	0.3154	0.1345	-0.2061	0.4118	0.1799	-0.0847
WDL	0.0462	0.0041	-0.0428	-0.1153	0.2843	0.2285	0.2795	0.1058	-0.1396	0.0342	-0.3468
STRM1	0.0883	-0.0836	-0.0162	0.1887	-0.4371	0.4055	0.0804	-0.0179	-0.1782	-0.0860	-0.0782
STRM2	-0.1218	0.1721	0.0801	-0.1974	0.3884	-0.1612	0.1140	-0.0921	0.3792	-0.0131	0.0641
AGE	0.0304	0.4267	-0.0953	0.1104	0.0849	0.1442	-0.1496	0.0933	-0.2177	0.0922	0.1052
EDUC	0.2048	-0.1501	-0.2975	-0.0618	0.2504	0.0815	-0.1616	-0.0243	-0.2160	0.0843	0.1721
OFFF	-0.0165	-0.1636	-0.0089	-0.1334	0.3222	0.1502	-0.3080	-0.1207	-0.1011	0.0387	0.0499
TOVR	0.0783	0.2856	0.0453	-0.0898	0.1143	0.2739	-0.2087	0.0561	0.1343	0.1851	0.0106
CSP	0.1737	-0.1217	-0.0489	0.1749	0.1370	0.2434	0.3494	0.0589	-0.0642	-0.0545	0.1565
EXP	0.0003	0.3921	-0.0745	0.2574	0.0848	0.0625	-0.0945	0.1783	-0.1926	0.1036	0.1400
COOP	-0.0380	-0.1981	-0.0632	0.1209	-0.0700	0.2008	-0.4874	0.2558	0.2850	-0.0753	0.0241
DHIA	0.2210	0.0023	-0.1090	0.1123	0.2280	-0.3240	0.0399	0.0939	0.1167	0.2086	-0.0429
LCES	0.1588	-0.0007	0.1865	0.0763	-0.0350	-0.0847	0.1827	0.4726	0.1614	0.0672	-0.0558
NRCSP	0.1871	-0.1572	-0.1026	-0.0793	0.0617	-0.1342	0.1352	0.0468	-0.3007	-0.2619	-0.1829
SEM	0.2368	-0.1184	-0.1308	0.0855	-0.1330	-0.1230	0.0664	0.2433	0.0569	0.1302	0.3952
RISK	-0.1173	0.2441	0.2756	-0.0097	-0.1323	-0.1188	0.0815	0.0562	-0.1397	0.1025	0.0615
SCAP1	0.2647	0.0555	0.3286	0.1145	0.0342	0.1077	-0.0166	-0.2486	0.1579	-0.1155	-0.1459
SCAP2	0.1868	-0.1200	0.2016	-0.1321	0.0814	0.0259	0.1845	0.0233	-0.0678	-0.2181	0.2266
SCAP3	0.2725	0.0614	0.3244	0.1096	0.0475	0.1420	-0.1083	-0.2704	0.0437	-0.0723	-0.1044
SCAP4	0.2647	0.0196	0.3146	-0.0034	0.0049	0.0838	-0.1992	0.2305	-0.0445	0.0028	-0.0436
SCAP5	0.2454	-0.0335	0.3429	-0.0790	0.1285	-0.0581	-0.0277	0.1096	-0.0771	0.0761	0.1743
ENV	-0.1928	0.1118	0.1658	0.0119	-0.1886	0.0270	0.1249	0.1343	0.2576	-0.1499	0.1250

Table D. (Continued).

Variables	EIGENVECTORS										
	PRIN12	**PRIN13**	**PRIN14**	**PRIN15**	**PRIN16**	**PRIN17**	**PRIN18**	**PRIN19**	**PRIN20**	**PRIN21**	**PRIN22**
COWS	-0.0567	-0.0452	0.0626	-0.0632	0.0289	-0.0123	-0.1185	-0.0355	-0.0157	0.0621	-0.08164
UIELD	0.1016	-0.0910	-0.0326	-0.0891	-0.4620	0.0942	-0.0866	0.3210	0.1118	0.2109	-0.0171
PASTU	0.4240	0.0439	0.0503	0.2120	0.3060	-0.0160	-0.1709	0.2608	0.0527	0.2475	-0.0431
OCROP	-0.2004	0.1624	0.0737	0.1533	0.1672	-0.0688	-0.0082	0.2856	0.2481	-0.1092	-0.1420
LAND	-0.0143	0.0922	-0.0696	-0.3787	0.0723	0.3496	0.1755	0.3385	-0.0522	0.1042	0.2207
PART	0.1434	0.0911	-0.1127	0.0822	-0.2175	0.2876	0.0584	0.0398	0.0782	0.2176	0.0643
FULT	0.0420	0.0670	0.0216	0.0601	-0.0324	0.0184	-0.1370	-0.0398	0.0876	0.0223	-0.1418
BSTR	0.1891	0.2052	-0.2143	0.0121	0.2170	-0.0632	0.1996	-0.0415	-0.0671	-0.1694	0.2292
NWTH	0.0853	0.1323	-0.1358	-0.1128	-0.1132	-0.5311	0.0505	0.0421	0.3548	-0.0171	0.2720
DEBT	-0.0160	-0.0744	0.0647	0.1737	-0.2854	-0.1395	-0.0030	0.0751	0.2791	0.0726	0.0920
HEL	0.1178	-0.0098	0.3311	-0.0124	-0.1119	0.3603	0.1639	-0.1501	-0.0787	-0.1349	-0.0410
WDL	-0.4106	0.0766	0.2910	-0.0372	-0.1597	-0.0475	-0.3893	0.0083	-0.0275	-0.0437	0.1702
STRM1	0.0665	-0.0153	-0.0394	-0.2097	0.0535	-0.1548	-0.1452	-0.0551	-0.0401	0.1297	-0.1451
STRM2	-0.0267	-0.1257	-0.1791	0.2061	0.0377	0.0517	-0.0953	-0.0029	0.0796	0.1250	0.0018
AGE	-0.0144	0.0230	0.0171	0.3213	-0.0574	-0.0237	0.0497	0.0481	0.0934	0.2361	0.0609
EDUC	0.0593	0.0983	-0.0155	-0.0766	0.0731	0.0467	-0.2098	-0.1196	0.1022	-0.1555	-0.2785
OFFF	-0.0503	0.5646	-0.1694	-0.1809	0.1208	0.0108	0.0103	0.0758	0.0598	0.2481	-0.0344
TOVR	-0.1305	-0.2703	0.2109	-0.1282	0.1709	-0.3117	0.2656	0.2906	-0.1665	0.1997	0.3483
CSP	0.0276	-0.0786	-0.3461	0.2536	-0.0053	0.0500	0.1916	-0.3020	0.0624	0.3723	-0.2245
EXP	0.1623	0.0764	0.0901	0.2401	0.0096	0.1485	-0.1470	-0.1475	-0.0940	-0.0929	-0.0582
COOP	-0.0770	0.0712	0.1314	0.0661	-0.0255	0.0312	0.1840	-0.1287	0.2198	-0.0671	0.2773
DHIA	0.1478	0.0757	0.1364	-0.3477	0.0335	-0.1789	0.1534	-0.4047	-0.1141	-0.0693	0.0233
LCES	-0.3620	0.1701	-0.1841	-0.0859	0.1564	0.2494	0.0334	0.1126	0.1671	-0.2188	-0.3116
NRCSP	-0.1370	0.1334	0.2690	0.2986	0.0014	-0.0211	0.5880	0.1027	-0.0381	-0.0616	0.0186
SEM	-0.1595	0.0185	0.0563	0.1052	0.2191	-0.0016	-0.1637	0.0652	-0.3780	0.2270	0.4235
RISK	-0.0503	0.0600	0.4102	-0.1421	0.1298	0.1270	0.0024	-0.2991	0.4227	0.4270	-0.0125
SCAP1	-0.0311	-0.0061	-0.0934	0.1294	0.1748	-0.0995	-0.0479	-0.1157	-0.0983	0.1302	0.0656
SCAP2	0.4428	-0.0366	0.2644	-0.0697	0.2402	0.0690	0.0651	0.2044	0.2414	-0.2487	0.0431
SCAP3	-0.0624	0.1824	0.0783	0.1935	0.1222	0.1085	-0.1463	-0.0046	-0.0602	0.0237	0.1236
SCAP4	-0.0179	-0.1908	-0.2334	-0.1978	-0.0840	0.1865	0.1027	-0.0234	0.0841	-0.1672	0.1684
SCAP5	0.2173	0.0721	0.1166	-0.0266	-0.2600	-0.0325	0.0167	0.1435	-0.2930	0.0165	-0.0971
ENV	0.0928	0.5487	0.0677	0.0516	-0.3248	-0.1336	0.0013	-0.0124	-0.2082	-0.0445	0.2006

Table D. (Continued).

Variables	EIGENVECTORS									
	PRIN23	PRIN24	PRIN25	PRIN26	PRIN27	PRIN28	PRIN29	PRIN30	PRIN31	PRIN32
COWS	-0.1174	0.1469	-0.0385	0.1746	0.0064	0.2251	-0.1017	-0.0739	-0.0511	0.7002
UIELD	0.1847	0.4160	-0.0564	-0.0897	0.1241	0.1680	-0.0451	-0.0325	-0.1021	0.0291
PASTU	0.0571	-0.2401	0.1285	0.1800	0.0303	0.0070	0.0668	0.1049	-.0.0253	0.0508
OCROP	-0.2825	-0.1870	0.1863	0.1884	0.1658	-0.0669	-0.1231	0.0676	0.1859	0.0268
LAND	0.0877	-0.1508	0.3047	-0.1031	0.1582	0.0052	-0.0686	0.0946	-0.1647	0.0652
PART	-0.0722	0.0298	0.1467	-0.1000	-0.1748	-0.3884	0.2002	0.0371	0.4340	-0.0879
FULT	-0.0334	-0.0978	-0.0597	-0.0454	0.1576	0.2034	-0.1632	0.0711	-0.4428	-0.5626
BSTR	0.0194	0.1028	-0.0991	-0.1383	0.2220	0.0802	-0.1020	-0.1759	-0.0181	0.1011
NWTH	0.0265	-0.2177	-0.3404	-0.1096	-0.1055	-0.0604	0.0377	-0.0530	0.1108	-0.0026
DEBT	0.2072	-0.0704	0.2024	0.0140	-0.2706	-0.0462	-0.0975	0.2933	-0.1384	0.1253
HEL	-0.0083	-0.1160	-0.2978	0.1025	-0.1802	0.1633	0.1337	-0.0367	0.1093	-0.0777
WDL	-0.2266	0.0198	0.1550	0.0364	0.1264	-0.0740	-0.0965	0.0761	0.1469	-0.1127
STRM1	-0.0505	0.1734	-0.0054	-0.0457	0.1530	-0.0072	0.3157	0.4892	0.0625	-0.0067
STRM2	0.0236	0.2181	-0.0975	-0.0514	0.3786	0.0371	0.2134	0.4139	0.1245	0.0133
AGE	-0.0319	0.1132	0.2360	0.2738	-0.0990	0.2312	0.4706	-0.1806	-0.1621	-0.0200
EDUC	0.4924	-0.2003	0.0444	-0.1507	0.2533	-0.0173	0.0667	-0.1697	0.2344	0.0807
OFFF	-0.2080	0.1830	-0.1630	0.1536	-0.1859	0.1948	0.0231	0.1823	-0.0108	-0.0458
TOVR	0.0641	0.1437	-0.0591	-0.0028	0.0482	-0.1697	-0.0771	-0.0605	0.0996	-0.1212
CSP	-0.2399	0.0954	0.0595	0.0967	0.1900	-0.1311	-0.0491	-0.1884	-0.0259	-0.0319
EXP	-0.1099	0.0475	-0.1318	-0.1932	-0.1421	-0.0402	-0.5083	0.3214	0.0971	0.0951
COOP	-0.1716	0.1391	0.1583	-0.3173	0.3178	-0.0419	-0.0472	-0.0938	-0.0324	0.0353
DHIA	-0.0172	0.1142	0.3816	0.1297	-0.0945	-0.2081	0.0591	0.1996	-0.1508	-0.0179
LCES	0.0388	0.0402	-0.0499	-0.2390	-0.2747	-0.0404	0.1267	-0.0355	-0.0582	0.0138
NRCSP	0.1756	0.0166	-0.0699	-0.0121	0.0849	0.0922	-0.0355	0.2679	0.0468	0.0354
SEM	0.1227	0.1274	-0.1756	0.0572	0.0054	0.0341	0.1530	-0.0044	0.1728	-0.1414
RISK	0.0896	-0.0565	-0.1048	0.0089	0.1683	0.148	0.1415	0.0201	0.0564	0.0347
SCAP1	0.1779	-0.0319	0.4154	-0.2571	-0.1858	0.4444	-0.0981	0.0089	0.1991	-0.0718
SCAP2	-0.1290	0.3819	0.0418	0.0092	-0.0715	-0.0617	-0.0919	-0.1886	0.0992	-0.1320
SCAP3	0.2350	-0.0139	-0.1344	0.0759	0.0675	-0.4941	0.0495	-0.0020	-0.4221	0.1500
SCAP4	0.0701	-0.1895	-0.0528	0.538	0.1745	0.0772	-0.2284	0.1145	0.1914	-0.0916
SCAP5	-0.3825	-0.3913	-0.0289	-0.2578	0.1835	0.0974	0.2395	0.0104	-0.0493	0.1362
ENV	0.2368	0.1299	0.1128	0.2205	0.1746	-0.0134	-0.1147	-0.1298	0.1582	-0.0473

APPENDIX E

PROBIT ANALYSIS WITH 30 VARIABLES

Table E. Results of the Probit Analysis – 30 Variables.

Variables	Conservation Tillage Practices				Cover Green Manure Crop				Critical Area Planting				Field Borders			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-2.5806	-0.3742	-1.0279		-2.6779	-0.9953	-1.0054		-4.5303**	-1.7934**	-1.6865**		-4.6015**	-1.8327**	-1.7680**	
COWS	0.0053	0.0008	0.0021		-0.0023	-0.0009	-0.0009		0.0077**	0.0030**	0.0029**		0.0044	0.0018	0.0017	
YIELD	0.0450**	0.0065**	0.0179**		0.0133*	0.0050*	0.0050*		0.0152**	0.0060**	0.0057**		0.0189**	0.0075**	0.0073**	
STRM1	0.6284	0.0911	0.2503		-0.1986	-0.0738	-0.0746		0.3580	0.1417	0.1333		-0.2625	-0.1045	-0.1009	
HEL	0.0825	0.0120	0.0329		-0.0649	-0.0241	-0.0244		0.0678	0.0268	0.0252		0.0265	0.0105	0.0102	
BSTR	-0.4411	-0.0640	-0.1757		0.1590	0.0591	0.0597		0.1086	0.0430	0.0404		0.0687	0.0274	0.0264	
LAND	-2.1673**	-0.3143**	-0.8633**		-0.2144	-0.0797	-0.0805		-0.3344	-0.1324	-0.1245		-0.1675	-0.0667	-0.0644	
NWTH	-0.3532	-0.0512	-0.1407		0.1640	0.0610	0.0616		-0.4033	-0.1597	-0.1501		-0.2067	-0.0823	-0.0794	
DEBT	0.2246	0.0326	0.0895		-0.2086	-0.0775	-0.0783		0.0593	0.0235	0.0221		-0.0466	-0.0186	-0.0179	
PASTU	-1.2412	-0.1800	-0.4944		-0.1632	-0.0607	-0.0613		0.9769*	0.3867*	0.3637*	0.3724**	0.7413	0.2953	0.2848	
OCROP	-0.3128	-0.0454	-0.1246		0.2853	0.1060	0.1071		0.3196	0.1265	0.1190		0.1051	0.0419	0.0404	
PART	-0.0650	-0.0094	-0.0259		0.1805	0.0671	0.0678		-0.1412	0.0559	-0.0526		0.0509	0.0203	0.0195	
FULT	-0.0045	-0.0007	-0.0018		-0.0434	-0.0161	-0.0163		-0.0846	-0.0335	-0.0315		-0.0019	-0.0008	-0.0007	
WDL	0.0777	0.0113	0.0310		0.3408**	0.1267**	0.1279**		-0.0456	-0.0180	-0.0170		0.1841	0.0734	0.0707	
STRM2	0.7122	0.1033	0.2837		-0.1940	-0.0721	-0.0728		0.0106	0.0042	0.0049		-0.4684	-0.1866	-0.1800	
AGE	-0.0138	-0.0020	-0.0055		-0.0317*	-0.0118*	-0.0119		-0.0164	-0.0065	-0.0061		-0.0024	-0.0010	-0.0009	
OFFF	0.7293	0.1058	0.2905		0.2447	0.0909	0.0919		0.3907	0.1546	0.1454		0.3587	0.1429	0.1378	
CSP	0.0736	0.0107	0.0293		-0.1918	-0.0713	-0.0720		-0.0053	-0.0021	-0.0020		-0.4271	-0.1701	-0.1641	
EDUC	-0.1240	-0.0180	-0.0494		0.1188	0.0442	0.0446		-0.2856	-0.1130	-0.1063		0.3718	0.1481	0.1429	
TOVR	1.3300**	0.1928**	0.5298**	0.3949**	0.5243	0.1949	0.1968		0.2972	0.1177	0.1106		0.7067*	0.2815*	0.2715*	0.2287*
EXP	0.0196	0.0028	0.0078		0.0116	0.0043	0.0044		0.0166	0.0066	0.0062		-0.0072	-0.0029	-0.0028	
DHIA	0.0102	0.0015	0.0041		-0.4105	-0.1526	-0.1541		-0.7702**	-0.3049**	-0.2867**	-0.2998**	-0.5446	-0.2169	-0.2092	
COOP	-1.7790**	-0.2580**	-0.7086**	-0.4446**	0.4098	0.1523	0.1539		-0.0686	-0.0271	-0.0255		0.1158	0.0461	0.0445	
LCES	0.4048**	0.0587**	0.1612		-0.0047	-0.0018	-0.0018		0.0907	0.0359	0.0338		0.1900**	0.0757**	0.0730**	
SEM	0.0459	0.0067	0.0183		0.0376	0.0140	0.0141		0.0139	0.0055	0.0052		0.0465	0.0185	0.0179	
NRCSP	0.2886	0.0418	0.1150		0.1913	0.0711	0.0718		-0.1919	-0.0760	-0.0715		-0.2143	-0.0854	-0.0823	
SCAP5	-0.8432**	-0.1223**	-0.3358**		0.0709	0.0264	0.0266		0.3259	0.1290	0.1213		0.1163	0.0463	0.0447	
SCAP2	-0.0218	-0.0032	-0.0087		0.2337	0.0869	0.0878		0.2306	0.0913	0.0858		-0.1117	-0.0445	-0.0429	
RISK	-0.6913	-0.1002	-0.2753		0.4474	0.1663	0.1680		0.1248	0.0494	0.0465		0.4268	0.1700	0.1640	
ENV	0.3609	0.0523	0.1438		0.1270	0.0472	0.0477		-0.0787	-0.0311	-0.0293		0.3083	0.1228	0.1184	
SCAP4	-0.1314	-0.0191	-0.0524		-0.2789	-0.1037	-0.1047		-0.0426	-0.0169	-0.0159		-0.5360**	-0.2135**	-0.2060	
LM	77.237				40.683				51.396				46.608			
McF	0.428				0.149				0.230				0.229			
Estrella	0.455				0.193				0.303				0.302			
AIC	1.122				1.629				1.562				1.568			
SC	-113.30				-144.70				-140.57				-140.91			
Predicted [a]	106 (85 %)				88 (71%)				88 (71%)				89 (72%)			
Lu [B]	-38.588				-69.985				-65.858				-66.195			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [a] : Proportion of correct predicted probabilities; and [b] : Values of the Log likelihood.

Table E. (Continued).

Variables	Filter Strips				Grassed Waterways				Heavy Use Area Protection				Regulating Water Drainage			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-3.3655	-1.1792	-1.3095		-4.7121**	-1.8255	-1.6586		-0.7598	-0.2568	-0.2690		-0.1851	-0.0738	-0.0738	
COWS	0.0037	0.0013	0.0014		-0.0031	-0.0012	-0.0011		-0.0026	-0.0009	-0.0009		0.0022	0.0009	0.0009	
YIELD	0.0170**	0.0060**	0.0066**		0.0205**	0.0080**	0.0072		0.0033	0.0011	0.0012		0.0025	0.0010	0.0010	
STRM1	-0.3446	-0.1207	-0.1341		-0.2977	-0.1153	-0.1048		0.3506	0.1185	0.1241		-0.0697	-0.0278	-0.0278	
HEL	0.1869	0.0654	0.0727		0.4238**	0.1642**	0.1492		0.0559	0.0189	0.0198		-0.2460*	-0.0981*	-0.0981*	
BSTR	0.2463	0.0863	0.0958		0.0220	0.0085	0.0077		-0.0464	-0.0157	-0.0164		0.2523	0.1045	0.1046	
LAND	-0.3268	-0.1145	-0.1271		0.7967	0.3087	0.2804		-0.6492	-0.2194	-0.2298		-0.4685	-0.1867	-0.1868	
NWTH	0.0946	0.0332	0.0368		-0.1705	-0.0660	-0.0600		-0.3424	-0.1157	-0.1212		0.4443	0.1771	0.1771	
DEBT	-0.2242	-0.0786	-0.0872		-0.1611	-0.0624	-0.0567		-0.3587**	-0.1213**	0.1270**		0.2308*	0.0920*	0.0920	
PASTU	0.7014	0.2458	0.2729		0.3833	0.1485	0.1349		-0.2195	-0.0742	-0.0777		-0.04271	-0.0170	-0.0170	
OCROP	0.0777	0.02723	0.0302		0.2482	0.0962	0.0874		0.2213	0.0748	0.0783		0.0047	0.0019	0.0019	
PART	0.0648	0.0227	0.0252		0.2010	0.0779	0.0707		0.0112	0.0038	0.0040		-0.0287	-0.0115	-0.0115	
FULT	-0.0698	-0.0245	-0.0272		0.1224	0.0474	0.0431		0.199	0.0405	0.0424		0.05415	0.0216	0.0216	
WDL	0.1848	0.0647	0.0719		0.2250	0.0872	0.0792		0.2182	0.0737	0.0772		-0.0556	-0.0221	-0.0222	
STRM2	0.0888	0.0311	0.0345		0.2702	0.1047	0.0951		-0.2077	-0.0702	-0.0735		-0.1685	-0.0672	-0.0672	
AGE	-0.0181	-0.0063	-0.0070		0.0138	0.0054	0.0049		0.0007	0.0003	0.0003		-0.0260*	-0.0104*	-0.0104	
OFFF	-0.4134	-0.1448	-0.1608		-0.1539	-0.0596	-0.0542		-0.1035	-0.0350	-0.0366		0.1661	0.0662	0.0662	
CSP	-0.2043	-0.0716	-0.0795		-0.2479	-0.0960	-0.0873		-0.2033	-0.0687	-0.0720		-0.0172	-0.0069	-0.0069	
EDUC	0.2203	0.0772	0.0857		-0.5813	-0.2252	-0.2046		0.4083	0.1380	0.1445		-0.0987	-0.0393	-0.0393	
TOVR	0.2381	0.0834	0.0926		-0.0206	-0.0080	-0.0072		0.4525	0.1530	0.1602		0.4664	0.1859	0.1860	
EXP	0.0076	0.0026	0.0029		-0.0179	-0.0069	-0.0063		-0.0035	-0.0012	-0.0012		0.0137	0.0055	0.0055	
DHIA	-0.7103**	-0.2489**	-0.2763*	-0.2363*	-0.707*	-0.2740*	-0.2490**	-0.2736**	-0.1189	-0.0402	-0.0421		-0.4933	-0.1966	-0.1967	
COOP	-0.0659	-0.0231	-0.0256		0.0199	0.0077	0.0070		-0.1611	-0.0544	-0.0570		0.5708	0.2275	0.2276	
LCES	0.1101	0.0386	0.0428		0.1001	0.0388	0.0352		0.0433	0.0147	0.0153		0.0781	0.0311	0.0311	
SEM	0.0918*	0.0322*	0.0357*		0.1404**	0.0544**	0.0494*		-0.0197	-0.0067	-0.0070		-0.0189	-0.0075	-0.0076	
NRCSP	-0.2949	-0.1033	-0.1148		-0.3735	-0.145	-0.1315		-0.4340	-0.1467	-0.1536		0.234	0.0931	0.0932	
SCAP5	-0.0385	-0.0135	-0.0150		-0.0137	-0.0053	-0.0048		0.0161	0.0054	0.0057		-0.1461	-0.0582	-0.0583	
SCAP2	-0.0592	-0.0208	-0.0230		-0.2655	-0.1028	-0.0934		0.4411	0.1491*	0.1561		0.2555	0.1018	0.1019	
RISK	-0.0740	-0.0259	-0.0288		0.6165	0.2388	0.2170		0.1877	0.0634	0.0664		0.2064	0.0823	0.0823	
ENV	-0.0727	-0.0255	-0.0283		-0.4496	-0.1742	-0.1583		-0.1010	-0.0341	-0.0357		-0.0237	-0.0095	-0.0095	
SCAP4	0.0689	0.0241	0.0268		0.3396	0.1316	0.1195		-0.1056	-0.0357	-0.0374		-0.0896	-0.0357	-0.0357	
LM	49.423				53.974				69.851				66.825			
McF	0.229				0.296				0.149				0.163			
Estrella	0.285				0.380				0.182				0.218			
AIC	1.495				1.462				1.560				1.660			
SC	-136.43				-134.34				-140.39				-146.62			
Predicted [a]	98 (79 %)				96 (77%)				89 (72%)				92 (74%)			
Lu [B]	-61.716				-59.627				-65.676				-71.919			

B: Values of the Parameters; M1: Margin al effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [a] : Proportion of correct predicted probabilities; and [b] : Values of the Log likelihood.

Table E. (Continued).

Variables	Riparian Forest Buffer				Sediment Basin				Streambank protection				Roof Runoff Management			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-1.4071	-0.4343	-0.5604		-0.1786	-0.0702	-0.0709		-0.9053	-0.2157	-0.0390		-1.4389	-0.5102	-0.5146	
COWS	0.0002	0.00006	0.00007		-0.00006	-0.00002	-0.00002		-0.0045	-0.0011	-0.0002		0.0055*	0.0020	0.0020*	
YIELD	0.0065	0.0020	0.0026		0.0050	0.0020	0.0020		0.0024	0.0006	0.0001		-0.0002	-0.00008	-0.00008	
STRM1	-0.0608	-0.0188	-0.0242		-0.3480	-0.1367	-0.1381		1.5073**	0.3591**	0.0649	0.2560*	-0.0393	-0.0139	-0.0140	
HEL	0.1182	0.0365	0.0471		0.1285	0.0505	0.0510		0.0714	0.0170	0.0031		0.0620	0.0220	0.0222	
BSTR	0.3132	0.0967	0.1247		0.8071**	0.3170**	0.3203**	02774**	1.4944**	0.3560**	0.0644	0.2517	0.0644	0.0228	0.0230	
LAND	-0.3701	-0.1142	-0.1474		-1.0904**	-0.4283**	-0.4327**		-1.5286**	-0.3642**	-0.0659		-1.3152**	-0.4664**	-0.4703**	
NWTH	0.1968	0.0607	0.0784		0.5571*	0.2188*	0.2210*	0.2043*	0.7911*	0.1885**	0.0341	0.0762	-0.2444	-0.0867	-0.0874	
DEBT	-0.1634	-0.0504	-0.0651		-0.1307	-0.0513	-0.0519		-0.2983	-0.0711	-0.0129	0.2587	-0.1386	-0.0492	-0.0496	
PASTU	0.7501	0.2315	0.2988		-0.0409	-0.0160	-0.0162		-0.4166	-0.0993	-0.0180		-0.0565	-0.0200	-0.0202	
OCROP	-0.1702	-0.0525	-0.0678		-0.3136	-0.1232	-0.1244		0.1573	0.0375	0.0068		0.2435	0.0863	0.0871	
PART	-0.0708	-0.0219	-0.0282		0.1363	0.0535	0.0541		0.1449	0.0345	0.0062		-0.02859	-0.0101	-0.0102	
FULT	0.0717	0.02214	0.0286		0.3338**	0.1311*	0.1324**		-0.4411**	-0.1051**	-0.0190		-0.1403	-0.0498	-0.0502	
WDL	-0.0431	-0.0133	-0.0172		0.0291	0.01142	0.0115		0.0193	0.0046	0.0008		0.0667	0.0237	0.0239	
STRM2	-0.3655	-0.1128	-0.1456		-0.4527	-0.1778	-0.1796		0.7258	0.1729	0.0313		0.1870	0.0663	0.0669	
AGE	-0.0147	-0.0045	-0.0059		-0.0214	-0.0084	-0.0085		-0.0517**	-0.0123**	-0.0022		-0.0012	-0.0004	-0.0004	
OFFF	-0.0233	-0.0072	-0.0093		0.5527	0.2171	0.2193		0.1854	0.0442	0.0080		0.4108	0.1457	0.1469	
CSP	-0.0184	-0.0057	-0.0073		0.1177	0.0462	0.0467		-0.1470	-0.0350	-0.0063		-0.1453	-0.0515	-0.0520	
EDUC	0.3305	0.1020	0.1316		0.2136	0.0839	0.0848		1.7054**	0.4063	0.0735		0.5238	0.1857	0.1873	
TOVR	0.0506	0.0156	0.0202		0.3645	0.1432	0.1446		0.5362	0.1277	0.0231		0.0737	0.0261	0.0264	
EXP	0.0078	0.0024	0.0031		-0.0129	-0.0051	-0.0051		0.0290	0.0069	0.0012		0.0062	0.0022	0.0022	
DHIA	-0.7518**	-0.2321**	-0.2995**	-0.2792**	-0.7277**	-0.2858**	-0.2887**	-0.2750**	-0.7901*	-0.1882*	-0.0340	-0.0156	-0.5454*	-0.1934*	-0.1950	-0.1645
COOP	0.2186	0.0675	0.0871		0.1869	0.0734	0.0742		0.6428	0.1531	0.0277		-0.0966	-0.0342	-0.0345	
LCES	0.1316	0.0406	0.0524		0.1363	0.0536	0.0541		-0.0660	-0.0157	-0.0028		0.0447	0.0158	0.0160	
SEM	-0.0154	-0.0047	-0.0061		0.0066	0.0026	0.0026		0.0900	0.0214	0.0039		-0.0035	-0.0012	-0.0013	
NRCSP	-0.6781*	-0.2093*	-0.2701*	-0.2555*	-0.1369	-0.0538	-0.0543		-0.5362	-0.1277	-0.0231		0.0106	0.0037	0.0038	
SCAP5	-0.0560	-0.0173	-0.0223		-0.0155	-0.0061	-0.0062		0.2018	0.0481	0.0087		0.0897	0.0318	0.0321	
SCAP2	0.3500	0.1080	0.1394		0.3572	0.1403	0.1417		-0.0045	-0.0011	-0.0002		0.0929	0.0329	0.0332	
RISK	0.5525	0.1705	0.2200		0.6878*	0.2702*	0.2729*	0.2617**	1.4024**	0.3341**	0.0604	0.0172	0.3317	0.118	0.119	
ENV	-0.2711	-0.0837	-0.1080		-0.0674	-0.0265	-0.0267		0.0475	0.0113	0.0020		0.2650	0.0940	0.0948	
SCAP4	0.0476	0.0147	0.0190		-0.2686	-0.1055	-0.1066		0.2653	0.0632	0.0114		-0.1438	-0.0510	-0.0514	
LM		63.719				44.413				72.164				64.82		
McF		0.171				0.247				0.380				0.145		
Estrella		0.200				0.321				0.434				0.182		
AIC		1.487				1.528				1.238				1.594		
SC		-135.88				-138.42				-120.48				-142.57		
Predicted [(a)]		94 (76 %)				88 (71%)				104 (84%)				86 (69%)		
Lu [(B)]		-61.167				-63.707				-45.764				-67.853		

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [(a)] : Proportion of correct predicted probabilities; and [(b)] : Values of the Log likelihood.

Table E. (Continued).

Variables	Waste Management System				Waste Storage Facilities				Waste Treatment Lagoon				Waste Utilization			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-2.8694	-0.0603	-0.2552		-3.0580	-0.9317	-0.7995		1.7487	0.4395	0.6303		-0.4285	-0.1063	-0.1552	
COWS	0.0203**	0.0004	0.0018		-0.0006	-.0002	-0.0001		-0.00008	-0.00002	-0.00003		-0.0003	-0.00008	-0.0001	
YIELD	-0.0008	-0.00002	-0.00007		0.0120	0.0037	0.0031		-0.0029	-0.0007	-0.0011		0.0036	0.0009	0.0013	
STRM1	1.1892	0.0250	0.1057		0.3885	0.1184	0.1016		0.6801	0.1710	0.2451		0.1989	0.0493	0.0721	
HEL	0.2585	0.0054	0.0230		0.2375	0.0724	0.0621		0.0089	0.0022	0.0032		0.2733*	0.0678*	0.0990	
BSTR	0.8095	0.0170	0.0720		0.3678	0.1121	0.0962		-0.2400	-0.0603	-0.0864		0.1298	0.0322	0.0470	
LAND	-1.5450*	-0.0325	-0.1374		-0.3324	-0.1013	-0.0869		-0.4124	-0.1037	-0.1486		-0.3403	-0.0844	-0.1233	
NWTH	0.9038	0.0190	0.0804		-0.0358	-0.0109	-0.0094		-0.0125	-0.0032	-0.0045		0.0446	0.0111	0.0161	
DEBT	-0.0087	-0.0002	-0.0008		-0.0635	-0.0194	-0.0166		-0.1905	-0.0479	-0.0687		0.0241	0.0060	0.0087	
PASTU	-0.0147	-0.0003	-0.0013		0.3510	0.1069	0.0918		-0.1577	-0.0396	-0.0568		-0.5649	-0.1401	-0.2046	
OCROP	1.055*	0.0222	0.0938		0.1571	0.0479	0.0411		-0.1608	-0.0404	-0.0579		0.3047	0.0756	0.1104	
PART	0.0022	0.00005	0.0002		0.0474	0.0144	0.0124		0.0039	0.0010	0.0014		-0.1129	-0.0280	-0.0409	
FULT	-0.5828	-0.0123	-0.0518		0.2548	0.0776	0.0666		-0.0552	-0.0139	-0.0199		0.0830	0.0206	0.0301	
WDL	0.1420	0.0030	0.0126		0.1163	0.0354	0.0304		-0.1745	-0.0438	-0.0629		-0.0426	-0.0106	-0.0154	
STRM2	-0.0192	-0.0004	-0.0017		0.2204	0.0672	0.0576		0.3019	0.0759	0.1088		0.3388	0.0840	0.1227	
AGE	-0.0668*	-0.0014	-0.0059		-0.0251	-0.0076	-0.0066		-0.0143	-0.0036	-0.0052		-0.0360*	-0.0089*	-0.0131	
OFFF	0.0201	0.0004	0.0018		0.6655	0.2028	0.1740		-0.0915	-0.0230	-0.0330		-0.8797**	-0.2182**	-0.3187**	-0.3400**
CSP	-0.4381	-0.0092	-0.0390		0.3121	0.0951	0.0816		0.2066	0.0519	0.0745		-0.1667	-0.04133	-0.0604	
EDUC	2.2486**	0.0473	0.2000	0.0415	0.2044	0.0623	0.0534		0.9152*	0.2300*	0.3298	0.2401*	0.3100	0.0769	0.1123	
TOVR	0.1743	0.0037	0.0155		-0.0975	-0.0297	-0.0255		0.3519	0.0885	0.1268		0.1822	0.0452	0.0660	
EXP	0.0467	0.0010	0.0042		-0.0047	-0.0014	-0.0012		0.0011	0.0003	0.0004		0.0241	0.0060	0.0087	
DHIA	-1.2566*	-0.0264	-0.1117	-0.2755	-0.7912**	-0.2411**	-0.2068*	-0.2701*	-0.0860	-0.0216	-0.0310		0.1115	0.0277	0.0404	
COOP	-0.1990	-0.0042	-0.0177		-0.0615	-0.0187	-0.0161		0.1458	0.0366	0.0525		0.2384	0.0591	0.0864	
LCES	0.0973	0.0020	0.0087		0.1271	0.0387	0.0332		0.0260	0.0065	0.0094		0.2066*	0.0512*	0.0748*	
SEM	0.3742**	0.0079	0.0333		0.0325	0.0099	0.0085		0.0823	0.0207	0.0297		-0.0327	-0.0081	-0.0119	
NRCSP	0.5405	0.0114	0.0481		0.5941	0.1810	0.1553		0.6260	0.1573	0.2256		1.0865**	0.2694**	0.3936*	0.2667
SCAP5	-0.1207	-0.0025	-0.0107		-0.0052	-0.0016	-0.0013		-0.2335	-0.0587	-0.0842		-0.1168	-0.0290	-0.0423	
SCAP2	-0.1056	-0.0022	-0.0094		0.0587	0.0179	0.0153		0.1144	0.0288	0.0412		0.0629	0.0156	0.0228	
RISK	2.3599**	0.0496	0.2098	0.6932**	1.0941**	0.3333**	0.2860*	0.3904**	0.4544	0.1142	0.1638		0.6835	0.1695	0.2476	
ENV	0.5900	0.0124	0.0525		0.1215	0.0370	0.0318		0.1690	0.0425	0.0609		0.0210	0.0052	0.0076	
SCAP4	0.0977	0.0021	0.0087		0.0555	0.0169	0.0145		0.1135	0.0285	0.0409		0.3666	0.0909	0.1328	
LM		74.257				99.398				88.850				65.313		
McF		0.535				0.260				0.177				0.295		
Estrella		0.502				0.308				0.185				0.329		
AIC		0.923				1.401				1.362				1.305		
SC		-100.93				-130.61				-128.16				-124.65		
Predicted [a]		114 (92 %)				97 (78%)				97 (78%)				96 (77%)		
Lu [B]		-26.211				-55.892				-53.448				-49.933		

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [a] : Proportion of correct predicted probabilities; and [b] : Values of the Log likelihood.

Table E. (Continued).

Variables	Nutrient Management				Pesticide Management			
	B	M1	M2	Δ	B	M1	M2	Δ
ONE	-4.5317*	-1.3435*	-1.4145		-3.3273	-1.2199	-1.3177	
COWS	-0.0062*	-0.0019*	-0.0019		-0.0014	-0.0005	-0.0006	
YIELD	0.0195**	0.0058**	0.0061*		0.0070	0.0026	0.0028	
STRM1	0.0281	0.0083	0.0088		0.8613**	0.3158**	0.3411**	0.3186**
HEL	0.1033	0.0306	0.0322		-0.0281	-0.0103	-0.0111	
BSTR	-0.0484	-0.0144	-0.0151		0.0563	0.0206	0.0223	
LAND	-0.5252	-0.1557	-0.1639		-0.1632	-0.0598	-0.0646	
NWTH	0.2219	0.0658	0.0693		-0.0607	-0.0223	-0.0240	
DEBT	-0.0139	-0.0041	-0.0043		0.0137	0.0050	0.00544	
PASTU	0.0765	0.0227	0.0239		0.955*	0.3502*	0.3783*	0.3110**
OCROP	0.2011	0.0596	0.0628		0.2496	0.09153	0.0989	
PART	-0.0714	-0.0212	-0.0223		0.1387	0.0508	0.0549	
FULT	0.5611**	0.1663**	0.1751**		0.0103	0.0038	0.0041	
WDL	0.1214	0.0360	0.0379		-0.1834	-0.0673	-0.0726	
STRM2	0.5138	0.1523	0.1604		0.5998*	0.2199*	0.2376*	0.2321*
AGE	0.0027	0.0008	0.0009		0.0179	0.0066	0.0071	
OFFF	0.1522	0.0451	0.0475		0.1449	0.0531	0.0574	
CSP	-0.4332	-0.1284	-0.1352		-0.0379	-0.0139	-0.0150	
EDUC	0.3100	0.0919	0.0968		1.1547**	0.4234**	0.4573**	0.3975**
TOVR	0.2857	0.0847	0.0892		0.2622	0.09612	0.1038	
EXP	-0.0166	-0.0049	-0.0052		-0.0263*	-0.0097*	-0.0104*	
DHIA	-1.0812**	-0.3205**	-0.3375**	-0.4065**	-0.3503	-0.1284	-0.1387	
COOP	0.8187*	0.2427*	0.2556	0.3052*	-0.0863	-0.0316	-0.0342	
LCES	0.3046**	0.0903**	0.0951*		0.1036	0.0380	0.0410	
SEM	0.0335	0.0099	0.0105		-0.0150	-0.0055	-0.0059	
NRCSP	0.3676	0.1090	0.1147		-0.1322	-0.0485	-0.0524	
SCAP5	-0.1514	-0.0449	-0.0473		0.3589*	0.1316*	0.1422*	
SCAP2	0.4771*	0.1414*	0.1489		-0.2351	-0.0862	-0.0931	
RISK	0.5447	0.1615	0.1700		0.3963	0.1453	0.1569	
ENV	-0.1656	-0.0491	-0.0517		0.3539	0.1297	0.1401	
SCAP4	0.1612	0.0478	0.0503		-0.0599	-0.0220	-0.0237	
LM	52.088				52.041			
McF	0.320				0,165			
Estrella	0.382				0.213			
AIC	1.347				1.608			
SC	-127.20				-143.38			
Predicted [(a)]	100 (81%)				86 (69%)			
Lu [(B)]	-52.483				-68.669			

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [(a)] : Proportion of correct predicted probabilities; and [(b)] : Values of the Log likelihood.

Table E. (Continued).

Variables	Fence				Prescribed Grazing				Trough or Tank			
	B	M1	M2	Δ	B	M1	M2	Δ	B	M1	M2	Δ
ONE	2.8083	0.6103	0.3775		2.0572	0.5056	0.4279		-0.8911	-0.2867	-0.2366	
COWS	-0.0007	-0.0002	-0.0001		0.0036	0.0009	0.0008		-0.0006	-0.0002	-0.0002	
YIELD	0.0096	0.0028	0.0013		0.0021	0.0005	0.0004		0.0060	0.0019	0.0016	
STRM1	-0.1947	-0.0423	-0.0262		-0.0898	-0.0221	-0.0187		0.1182	0.0380	0.0314	
HEL	-0.0094	-0.0020	-0.0013		0.0423	0.0104	0.0088		0.1704	0.0548	0.452	
BSTR	0.3832	0.0833	0.0515		0.4449	0.1093	0.0925		0.1531	0.0493	0.0406	
LAND	0.2247	0.0488	0.0302		-1.7600**	-0.4326**	-0.3661		-0.2840	-0.0914	-0.0754	
NWTH	0.1399	0.0304	0.0188		0.3997	0.0982	0.0831		0.0692	0.0223	0.0184	
DEBT	0.0858	0.0187	0.0115		-0.0913	-0.0225	-0.0190		-0.0521	-0.0168	-0.0138	
PASTU	-1.2566	-0.2731	-0.1689		1.0595*	0.2604	0.2204	0.3406	0.0812	0.0261	0.0216	
OCROP	-0.2308	-0.0502	-0.0310		-0.0094	-0.0023	-0.0019		-0.1831	-0.0589	-0.0486	
PART	-0.0084	-0.0018	-0.0011		-0.2927*	-0.0719*	-0.0609		-0.0829	-0.0267	-0.0220	
FULT	0.0497	0.0108	0.0067		0.0256	0.0063	0.0053		0.0847	0.0272	0.0224	
WDL	-0.1391	-0.0302	-0.0187		-0.2365	-0.0581	-0.0492		-0.1044	-0.0336	-0.0277	
STRM2	-0.2807	-0.0610	-0.0377		-0.2499	-0.0614	-0.0520		-0.1218	-0.0392	-0.0323	
AGE	-0.0547**	-0.0119**	-0.0074		-0.0307	-0.0075	-0.0064		0.0054	0.0017	0.0014	
OFFF	-0.6079	-0.1321	-0.0817		-0.0214	-0.0053	-0.0045		-0.0359	-0.0115	-0.0095	
CSP	0.2793	0.0607	0.0375		-0.7601*	-0.1868*	-0.1581	-0.0983	-0.1766	-0.0568	-0.0469	
EDUC	0.2478	0.0539	0.0333		0.5759	0.1415	0.1198		0.5020	0.1615	0.1333	
TOVR	0.6766	0.1470	0.0909		-0.3683	-0.0905	-0.0766		-0.3971	-0.1278	-0.1054	
EXP	0.0032	0.0007	0.0004		0.0004	0.0001	0.0001		-0.0020	-0.0006	-0.0005	
DHIA	-0.2350	-0.0511	-0.0316		-0.8377*	-0.2059*	-0.1742	-0.2538*	-0.2402	-0.0773	-0.0638	
COOP	0.7431	0.1615	0.0999		-0.1311	-0.0322	-0.0273		0.6039	0.1943	0.1603	
LCES	0.1566	0.0340	0.0210		0.4560**	0.1121**	0.0949		0.1210	0.0389	0.0321	
SEM	-0.0345	-0.0075	-0.0046		-0.0463	-0.0114	-0.0096		0.1054	0.0339	0.0280	
NRCSP	-0.0468	-0.0102	-0.0063		-0.3981	-0.0978	-0.0828		-0.0194	-0.0062	-0.0052	
SCAP5	0.2102	0.0457	0.0283		0.0227	0.0056	0.0047		0.1039	0.0334	0.0276	
SCAP2	0.1389	0.0302	0.0187		0.0143	0.0035	0.0030		0.0553	0.0178	0.0147	
RISK	0.5895	0.1281	0.0792		0.3708	0.0911	0.0771		0.6016*	0.1936*	0.1598	0.1984
ENV	-0.1139	-0.0248	-0.0153		0.0623	0.0153	0.0130		-0.2039	-0.0656	-0.0541	
SCAP4	-0.3076	-0.0669	-0.0413		0.3066	0.0753	0.0638		-0.0353	-0.0114	-0.0094	
LM		67.041				80.640				75.490		
McF		0.203				0.391				0.164		
Estrella		0.204				0.446				0.196		
AIC		1.301				1.225				1.519		
SC		-124.40				-119.66				-137.89		
Predicted [(a)]		102 (82%)				105 (85%)				95 (77%)		
Lu [(B)]		-49.690				-44.942				-63.176		

B: Values of the Parameters; M1: Marginal effects at mean values of all variables; M2: Marginal effect at selected values of the dummies; Δ : Discrete changes for specific dummies; ** : Values significant at 5% ; * : Values significant at 10%; [(a)] : Proportion of correct predicted probabilities; and [(b)] : Values of the Log likelihood.

VITA

Noro C. Rahelizatovo was born in Antananarivo, Madagascar. Upon completion of a high school degree at Lycee Jules Ferry, Antananarivo, in 1977, she performed the mandatory "national" service. She completed her undergraduate degree in 1982, and graduated as an agricultural engineer, specialized in Food Industry, from the University of Madagascar in 1984.

She has worked at the Service of project Monitoring and Evaluation, Department of Programming, Ministry of Agriculture, since 1985. She has been responsible of the Division of Methodology, Coordination and Synthesis. She completed two years of professional training at the Institute of Madagascar for Techniques of Planning to enhance her professional abilities, and graduated as a Planner in 1990. In 1993, she was responsible of the Service of Programming, Department of Programs and Finance, Ministry of Agriculture.

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