Factors Influencing the Implementation of Best Management Practices in the Dairy Industry

Noro C. Rahelizatovo
and
Jeffrey M. Gillespie

Department of Agricultural Economics and Agribusiness
Louisiana State University
101 Ag. Admin. Bldg.
Baton Rouge, LA 70803-5604
jmgille@lsu.edu

Selected Paper prepared for the presentation at the southern Agricultural Economics Association Annual Meeting, Mobile, Alabama, February 1-5, 2003.

Introduction

The traditional view of the agricultural community as a good steward of the environment has been challenged by increasing concern about the complex relationships between agricultural production activities and environmental quality. Many have pointed to agriculture as a nonpoint source of water pollution. Pollutants such as sediment, nutrients, pesticides, salt, and pathogens originate from agriculture activities, reach water resources through runoff, leaching, rainfall and snow melt, and impair surface, ground and coastal waters. The Coastal Zone Management Act of 1972 and the Coastal Zone Act Reauthorization Amendments of 1990 require specific measures to handle agricultural nonpoint sources of water pollution. Voluntary implementation of BMPs, which consist of specific sets of effective and practical means to reduce water pollution, have been promoted.

The Louisiana dairy industry has experienced the same basic trend as the nation, toward fewer, yet larger units of production, over the past two decades. Such structural change has been emphasized in Rahelizatovo and Gillespie's investigation of the changes in dairy farm size, entry and exit of farms in the Louisiana dairy industry in 1999. 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. 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. Furthermore, the concentration of fecal coliform bacteria in streams and other water bodies has raised major concern in Louisiana over the past twenty years. 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. This study aims to examine the current adoption of best management practices (BMPs) by Louisiana dairy producers. The conduct of univariate and multivariate probit analyses allows for investigating the economic and non-economic determinant factors of producers' decision to adopt one, two or a set of practices.

Literature

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. Since the publication of his work, the economics of technology adoption has captured researchers' interests, yielding hundreds of publications. Researchers have investigated the different aspects of producers' adoption decision and examined the likely determinant factors influencing increased technology adoption (Caswell and Zilberman, 1985; Shields *et al.*, 1993; Ghosh *et al.*, 1994; Davis and Gillespie, 2000; Moser and Barrett, 2002). Some pointed out the need for appropriate econometric tools to account for the interrelationships among adoption decisions (Feder *et al.*, 1985; Zepeda, 1994; Dorfman, 1996; El-Osta and Morehart, 1999). Studies on the adoption of environmentally-sound technologies explored the role of factors such as producers' awareness of soil erosion, quality of information, land tenure, and economic incentives on the voluntary adoption of management practices (Gould *et al.*, 1989; Barbier, 1990; Govindasamy and Cochran, 1995; Westra and Olson, 1997; Cardona, 1999; Soule *et al.*, 2000; Ipe *et al.*, 2001; Cooper, 2001).

Data and Methods

A state-wide survey of the entire population of Louisiana dairy producers (428) was conducted in Summer, 2001 to collect data related to dairy production characteristics, producers' characteristics, risk preference and environmental attitude, social capital variables, farm characteristics, and current adoption of the twenty one BMPs. A total of 131 surveys were returned with 124 completed.

Econometric Models

This study investigates the likelihood of a producer of a specific description to adopt one or more management practices. The conduct of a probit analysis on each individual BMP allows for the assessment of the probability of a dairy producer to implement a specific BMP based on the economic and non-economic factors hypothesized as determinant in the dairy producer's decision to adopt. The linear random utility assumption is expressed in equation (1), where

$$(1) \qquad \begin{cases} U_{i0} = \overline{U}_{i0} + e_{i0} = \mathrm{z}_{i0}'d + \mathrm{w}_{i0}'g_0 + e_{i0} \\ U_{i1} = \overline{U}_{i1} + e_{i1} = \mathrm{z}_{i1}'d + \mathrm{w}_{i1}'g_1 + e_{i1} \end{cases}$$

$\overline{U}_{ij}$ = 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 individual i would choose "to adopt a BMP" (y_i =1) versus "not to adopt a BMP" (y_i = 0) is expressed as:

$$(2) \qquad p_i = prob\ (y_i = 1 \mid x) = prob\ (y_i^* > 0) = prob(e_i^* > -x_i'b) = F(b'X)$$

where $y_i^* = U_{i1} - U_{i0}$ (the latent variable) $= (z_{i1} - z_{i0})'d + w_i'(g_1 - g_0) + (e_{i1} - e_{i0}) =$ $[(z_{i1} - z_{i0})', w_i']\begin{bmatrix} d \\ g_1 - g_0 \end{bmatrix} + e_i^* = x_i'b + e_i^*$; and F = cumulative distribution function of e_i^* evaluated at $x_i'b$.

The unobservable latent variable y_i^* is linked to the observed binary variable y_i:

$$(3) \qquad y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \leq 0 \end{cases}$$

The marginal effect associated with a continuous explanatory variable x_k on the probability p_i, holding the other variables constant, can be derived as in (4) where f represents the probability

$$(4) \qquad \frac{\partial p_i}{\partial x_{ik}} = f(x_i'b)b_k$$

density function of a standard normal random variable. Estimates of marginal effects at the mean values of all independent variables constitute the commonly reported summary measure in many studies.

Multivariate probit analysis is conducted to determine the types of producers that adopt two or more practices. The general formulation is as expressed in equation (6) 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.

$$(6) \qquad \begin{cases} y_1^* = b_1'X_1 + e_1, \quad y_1 = 1 \text{ if } y_1^* > 0, \text{ and 0 otherwise} \\ y_2^* = b_2'X_2 + e_2, \quad y_2 = 1 \text{ if } y_2^* > 0, \text{ and 0 otherwise} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ y_M^* = b_M X_M + e_M, \quad y_M = 1 \text{ if } y_M^* > 0, \text{ and 0 otherwise} \end{cases}$$

The probabilities that enter the likelihood function would become:

$$(7) \qquad \text{prob}(Y_{i1}, Y_{i2}, \ldots, Y_{iM} / x_{i1}, x_{i2}, \ldots, x_{iM}) = \text{MVN}(TZ, TRT`)$$

where MVN stands for multivariate normal distribution; T is a diagonal matrix with element $t_m = 2y_m - 1$; Z = a vector with elements $z_{iM} = b_M' x_{iM}$; R = correlation matrix of the errors terms; and m = 1, 2, . . ., M. The marginal effects for the continuous explanatory variables can be 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 (8).

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

(8)
$$= \sum_{m=1}^{M} \left\{ \left[\frac{\partial \text{ prob}(Y_1 = 1, Y_2 = 1, ...Y_M = 1)}{\partial Z_m} \right] c_m * \frac{1}{\text{prob}(Y_2 = 1, ..., Y_M = 1)} \right\}$$
$$- E_1 * \sum_{m=2}^{M} \left\{ \left[\frac{\partial \text{ prob}((Y_2 = 1, ..., Y_M = 1)}{\partial Z_m} \right] c_m * \frac{1}{\text{prob}(Y_2 = 1, ..., Y_M = 1)} \right\}$$

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

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, expressed in equation (9) were conducted as an alternative to marginal effects.

(9)
$$\frac{\Delta\, prob(Y_1, ..., Y_m | X)}{\Delta x_k} = prob(Y_1, ..., Y_m | X, x_k + d) - prob(Y_1, ..., Y_m | X, x_k)$$

where d is the increment in the value of variable of interest x_k. Discrete changes in the probabilities were estimated for variables that yielded statistically significant coefficients for b.

The Binary Dependent Variables

Each management practice included in the set of 21 BMPs for the Louisiana dairy industry was assumed to define one equation in each probit model and the subsequent analysis. 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 management practices were grouped into four main categories for the purpose of multivariate probit analysis, based on each practice primary objective. 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.

Factors Influencing Dairy Producers' Decisions to Adopt BMPs

Larger sized farms have generally been associated with an increased likelihood to adopt technology. Adoption of a new technology often involves high initial outlay and farmers with greater resources are better able to afford the technology. 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 and characterize farm operator management ability. It has usually been incorporated in technological adoption studies as an endogenous variable because technology affects productivity. 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. 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 one of the common tools for managing agricultural risks associated with yield, price and income. Risk aversion would drive farmers to engage in alternative enterprises. 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. Tenants' lack of motivation to adopt would be due to the perception of benefits accruing to the landowner, and not to the renter. 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. Both pasture-based and free-stall dairy farms were expected to be involved in the runoff and waste management practices. However, 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, and 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. 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. The ambiguous effects of debt-to-asset ratio on adoption were discussed by Fernandez-Cornejo *et al.* (1994). In this study, the sign of variable DEBT is to be explored.

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. 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 and was expected to increase the implementation of BMPs, especially those such as streambank and shoreline protection. 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. STRM2 would likely reduce the adoption of BMPs.

The roles of age and educational attainment in farmers' decisions to adopt technology have been shown in previous studies. 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 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, variable 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 encourage the adoption of conservation practices as farm operators would have an incentive to maintain productivity of soil for future generations. Variable 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 have a positive sign. 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.

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 Master 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.

Risk and uncertainty have been discussed in previous empirical studies as impeding factors to technology adoption. 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 the 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.

Farmer's behavior toward the environment was assessed based on the New Environmental Paradigm (NEP) scale developed by Dunlap *et al*. in 2000. Variable ENV described the NEP score associated with the dairy operator's environmental attitude and 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. 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.

Results

Different rates of adoption were found for each BMP (Table 1). 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, varying from 70 percent (for waste storage facility) to 83 percent (for waste management system). 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.

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. Selected results from the probit analysis are presented in Table 2.

Fewer variables were significant as more equations were considered in the multivariate probit analysis. Selected results are presented in Table 3. 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.

Conclusions

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: (i) the positive influence of farm size on the adoption of BMPs that are not particularly capital-intensive in nature, emphasizing the possibility of larger farms appropriating the learning costs as fixed expenses, as suggested by Feder *et al.* (1985); (ii) the effect of milk productivity per cow on the increased adoption of six BMPs, suggesting that better managers are likely to adopt practices that ensure the long-run viability of their operations; (iii) the increased effect of frequent meetings with LCES personnel on the adoption of eight BMPs, underscoring the importance of information dissemination in inducing adoption and the effectiveness of LCES in providing BMP information to producers; (iv) the influence of producer's risk aversion on the adoption of six of the more capital intensive BMPs likely to ensure long-run economic viability of the land and avoidance of the risk associated with decreased productivity resulting from unusually heavy rainfall events; (v) the consistent negative effect of membership in DHIA on the adoption of nine somewhat capital intensive BMPs, suggesting 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; (vi) the lower probability that older producers had adopted BMPs that required substantial initial capital investments, as producers with short planning horizons would unlikely be able to benefit from the full stream of benefits, but must absorb the full costs; and (viii) the greater likelihood of more highly educated producers to adopt BMPs. Higher educational attainment allows farmers not only greater access to information, but also recognition of the benefits and costs of alternative management strategies and greater ability to adjust to changes.

The overall findings suggest the need to address (i) the lack of knowledge among dairy producers about BMPs, 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; (ii) the low rate of producers having a dairy farm plan with NRCS; and (iii) 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.

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Table 1. Dairy Producers Adoption Rates of BMPs.

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

Table 2. Selected Results from the Probit Analysis of Each Individual BMP.

Variables	Conservation Tillage		Waste System		Waste Storage Facility		Waste Treatment Lagoon		Waste Utilization		Fencing		Prescribed Grazing		Trough or Tank	
	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
ONE	-1.2796	-0.2739	-3.9237	-0.1248	-1.4841	-0.4799	1.0700	0.2874	-0.9313	-0.2416	0.3830	0.0944	0.2727	0.0731	-1.3830	-0.4507
COWS	0.0047*	0.0010*	0.0120*	0.0004	0.0027	0.0009	0.0002	0.00006	-0.0003	-0.00007	0.0008	0.0002	0.0014	0.0004	-0.0008	-0.0003
YIELD	0.0247**	0.0053**	0.0067	0.0002	0.0133*	0.0043*	-0.0036	-0.0010	0.0011	0.0003	0.0067	0.0017	0.0028	0.0008	0.0055	0.0018
STRM1	0.2251	0.0482	0.9184	0.0292	0.2754	0.0891	0.4922	0.1322	-0.0561	-0.0146	-0.0465	-0.0115	0.1342	0.0360	0.1797	0.0586
HEL	0.1564	0.0335	0.2287	0.0073	0.2263	0.0732	-0.0396	-0.0106	0.2780*	0.0721**	-0.0042	0.0010	0.0252	0.0068	0.1242	0.0405
BSTR	-0.3825	-0.0819	0.8048	0.0256	0.3232	0.1045	-0.3992	-0.1072	0.0260	0.0067	0.2944	0.0725	0.3468	0.0929	0.0517	0.0169
LAND	-1.2034**	-0.2576*	-1.2755*	-0.0406	-0.5273	-0.1705	-0.3693	-0.0992	-0.2180	-0.0565	0.4273	0.1053	-1.6157**	-0.4330**	-0.3256	-0.1061
NWTH	-0.1645	-0.0352	0.6661	0.0212	0.0862	0.0279	0.0362	0.0097	0.0270	0.0070	0.1030	0.0254	0.3349	0.0897	0.0274	0.0089
PASTU													1.0278*	0.2754*		
OCROP			0.7589	0.0241					0.3621	0.0939						
PART													-0.1793	-0.0481		
AGE	0.0063	0.0014	-0.0314	-0.0010	-0.0241*	-0.0078*	-0.0082	-0.0022	-0.0176	-0.0046	-0.0408**	-0.100**	-0.0248	-0.0066	0.0021	0.0007
OFFF	0.8307**	0.1778**	0.1098	0.0035	0.7808**	0.2525*	-0.1198	-0.0322	-0.8556**	-0.2220**	-0.3691	-0.0909	0.0449	0.0120	0.0379	0.0124
CSP													-0.7658**	-0.2052**		
EDUC			1.8045**	0.0574			0.7408*	0.1990*								
DHIA	0.0462	0.0099	-1.1347**	-0.0361	-0.6279*	-0.2030**	0.0776	0.0209	0.1439	0.0373	-0.2721	-0.0670	-0.5610	-0.1503	-0.1052	-0.0343
COOP	-1.6858**	-0.3608**	0.0569	0.0018	-0.3425	-0.1107	0.1648	0.0443	0.1889	0.0490	0.6007	0.1480	-0.0128	-0.0034	0.6575*	0.2143*
LCES	0.3162**	0.0677**	0.1189	0.0038	0.1356*	0.0438**	0.0392	0.0105	0.2033**	0.0528**	0.0923	0.0227	0.3775**	0.1012**	0.0751	0.0245
SEM	0.0037	0.0008	0.3642**	0.0116	0.0362	0.0117	0.0562	0.0151	-0.0211	-0.0055	-0.0063	-0.0016	-0.0060	-0.0016	0.1267*	0.0413*
NRCSP									0.9276**	0.2406**						
SCAP5	-0.4797**	-0.1027**	-0.0714	-0.0023	-0.0125	-0.0040	-0.1577	-0.0424	-0.0635	-0.0165	0.2407	0.0593	-0.1088	-0.0292	0.0276	0.0090
SCAP2	-0.1251	-0.0268	0.0280	0.0009	0.0694	0.0225	0.1592	0.0428	0.1049	0.0272	0.0751	0.0185	0.0778	0.0209	0.1177	0.0383
RISK	-0.2164	-0.0463	2.0730**	0.0659	0.7709**	0.2493**	0.3287	0.0883	0.7037*	0.1825*	0.5752*	0.1417*	0.2830	0.0758	0.4718	0.1538
ENV	0.1697	0.0363	0.5993	0.0191	0.0331	0.0107	0.0532	0.0143	-0.0149	-0.0039	-0.1495	-0.0368	0.0408	0.0109	-0.1773	-0.0578
SCAP4									0.3221	0.0836			0.3702	0.0992		
LM	51.576		44.312		38.864		36.630		47.270		46.349		54.976		49.925	
McF	0.288		0.501		0.194		0.113		0.259		0.135		0.3530		0.129	
Estrella	0.309		0.468		0.231		0.118		0.290		0.136		0.4044		0.155	
AIC	1.064		0.777		1.273		1.124		1.185		1.160		1.125		1.353	
SC	-91.38		-76.360		-104.32		-103.45		-103.09		-97.28		-100.76		-109.24	
Predicted [a]	98 (79 %)		113 (91%)		96 (77%)		101 (81%)		98 (79%)		100 (81%)		103 (83%)		94 (76%)	

B: Values of the Parameters; M: Marginal effects at mean values of all variables; ** : Values significant at 5% ; * : Values significant at 10%; and [a] : Proportion of correct predicted probabilities.

Table 3. Selected Results from the Multivariate Probit Analysis.

Variables	**Waste Storage Facility – Waste Treatment Lagoon – Waste utilization**				**Prescribed Grazing – Fencing -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 $(l = 1)$ and significant variables in the probit analysis; and [(d)] : Constrained model specified from PCA $(l = 1)$.