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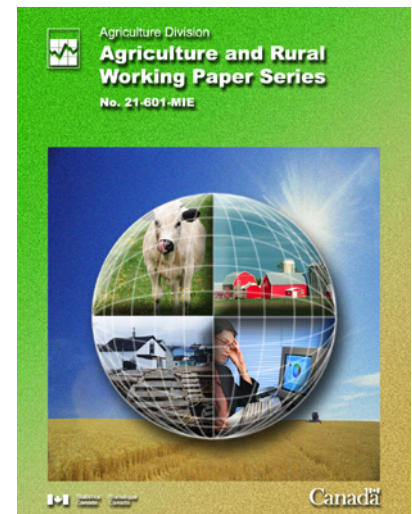
## Research Paper

# Factors Leading to the Implementation of Beneficial Management Practices for Manure Management on Canadian Hog Operations

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# Factors Leading to the Implementation of Beneficial Management Practices for Manure Management on Canadian Hog Operations

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### Note of appreciation

Canada owes the success of its statistical system to a long standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued cooperation and goodwill.

# **Factors leading to the implementation of Beneficial Management Practices for manure management on Canadian hog operations**

## **Abstract**

Beneficial Management Practices (BMPs) are practices scientifically proven to reduce the impact of agricultural activities on soil and water resources while maintaining the economic viability of the industry. BMPs on manure management provide a range of management options for the collection, storage, transportation, treatment and application of manure from hog farms.

This paper uses a logistic regression model and Statistics Canada data from the 2001 Farm Environmental Management Survey and the 2001 Census of Agriculture to determine the primary factors affecting the implementation of BMPs for manure management by hog producers. Results indicate that the odds of implementing BMPs on hog farms was highest for farms located in Quebec, farms with formal manure management plans, non-family incorporated farms, farms with a female as main operator and larger farms. The effect of age was not significant.

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## **Introduction**

Over the last few years, the rapid expansion of large livestock operations has fuelled heated debates in many rural communities across Canada. Proposals for new hog operations, among others, have encountered vocal opposition from neighbours and residents in the community. Construction of new “mega-farms” or “factory” hog farms are often in media headlines. Hog manure is often publicly perceived as particularly offensive, and hog operations elicit a large number of complaints from neighbours (Caldwell 2001 and Landry 2001).

Accompanying the expansion of hog operations are growing concerns about the storage, use and treatment of manure, mainly because millions of litres of liquid manure are being stored in one location. Hog manure is perceived as a potential source of water and air pollution. Environmental concerns include: the lack of treatment before raw liquid manure is spread on land (odour nuisance and potentially harmful pathogens); potential spills, leaks and runoff into surrounding land and watercourses; and greenhouse gas emissions (Chambers et al. 2001, Olsen 2001, Simard 2001, and Carter and Owen 2000). Legislation and public pressures have made manure management an important consideration in farm management.

Beneficial Management Practices (BMPs) are practices, or system of practices, scientifically proven to reduce the impact of agricultural activities on soil and water resources while maintaining the economic viability of the agriculture industry (Bailey and Waddell 1978). They are standards or guidelines, set forth by farmers, researchers, agribusiness professionals and governments, covering all sectors and include a comprehensive list of topics such as legal issues and conflict prevention, environmental risks associated with some waste management practices, management and facility options for dealing with manure, and the potential impacts of various options. BMPs can be specific to regions and operation types. BMPs on manure management provide a range of management options for the collection, storage, transportation, treatment and application of manure from hog operations.

A few studies have suggested that farmers may not be adopting BMPs as widely as anticipated by governments and industries due to certain socio-economic factors (Hindsley 2002, Kehrig 2002, Caswell et al. 2001, and Lafond et al. 1994). There has also been research work that looked into how knowledge and perceptions held by farm operators affect the

implementation of BMPs or other standard farm management practices (Hindsley 2002, Traore et al. 1998, Lohr and Park 1995, and Fuglie 1999).

Previous studies focused on crop operations and/or crop management practices such as tillage, nutrient (fertilizer) management, irrigation, soil erosion, drainage, and pesticide and herbicide use (Hindsley 2002, Caswell et al. 2001, Fuglie 1999, Traore et al. 1998, Lohr and Park 1995, Lafond et al. 1994, Gould et al. 1989). Many studies were small in scale, region specific, and included mainly family farms. Very little has been done to analyse the constraints associated with the adoption of BMPs by livestock operations and, specifically, for manure management.

An analysis of data from the 2001 Farm Environmental Management Survey (FEMS) and the 2001 Census of Agriculture aims to illustrate the extent to which various socio-economic factors can affect the implementation of BMPs for manure management by hog producers.<sup>1</sup>

## **Methodology**

### **Logistic regression model**

It is assumed that when farmers decide to implement BMPs, their decision can be motivated by farm and operator characteristics such as farm location, number of pigs, value of land and buildings, gross farm cash receipts, development of formal manure management plan, farmland area, farming intensity, specialization in pig farming, operating arrangement, age of operator, gender of operator and work off-farm. The goal is to model the likeliness of the decision to implement BMPs on the explanatory variables (farm and operator characteristics).

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1. Hog producers or hog operations are farms that reported having at least one hog on their agricultural operation on May 15<sup>th</sup>, 2001, and reported gross farm receipts of \$10,000.

A logit model<sup>2</sup> is designed to estimate the parameters of a multiple regression analysis in which the dependent variable is categorical (dichotomous in this case, the dependant variable takes the value of 1 when the farmer implements BMPs and 0 otherwise).

The model expresses the conditional log odds of implementing BMPs as a linear function of a set of explanatory variables. The model is specified as:

$$\log\left(\frac{P_i}{1-P_i}\right) = \alpha + \sum_{k=1}^K \beta_k X_{ik} + \varepsilon_i$$

where  $P_i$  is the conditional probability that a farm  $i$  implements BMPs ( $P(Y_i)=1$ ) given the explanatory variables in the model;  $1-P_i$  is the conditional probability that a farm does not implement BMPs;  $\left(P_i/1-P_i\right)$  is the odds or the relative probability of falling into one of the two categories of interest;  $\alpha$  (the intercept) and  $\beta_k$  (the predicted odds) are the logistic regression parameters to be estimated;  $X_{ik}$  is the  $k^{\text{th}}$  explanatory variable associated with the  $i^{\text{th}}$  farm in the model; and  $\varepsilon_i$  is the random error associated with the  $i^{\text{th}}$  farm. Odds ratios are obtained by exponentiating the logistic regression parameters.

SUDAAN<sup>3</sup> statistical package was used to estimate  $\beta$  by solving the weighted score equations. Variance was estimated via implicit Taylor linearization.

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2. For more details, refer to Pindyck and Rubinfeld (1981), Aldrich and Nelson (1985) and Gujarati (1988)  
 3. For more details, see SUDAAN, Research Triangle Institute, User manual (2001).

## Explanatory variables

The justification for including the following independent variables in the logistic regression is presented in this section:

### 1. Region

BMPs implementation may differ between various geographical regions in Canada. Farms in each province operate in accordance with regional and provincial regulations and/or guidelines on farm management practices; consideration for climate and soil conditions; and awareness of public concerns, each of which may differ greatly from region to region. In this study, geographical regions were set at the province level, with the exception of the Atlantic Provinces, which were grouped due to data limitation. Quebec was set as the reference category because of the relatively stringent standards for the operation of livestock farms and manure management enforced in the province<sup>4</sup>.

It is expected that, compared to Quebec, hog producers in other regions will be less likely to implement BMPs. In the Prairie Provinces, BMPs are generally voluntary, and there are fewer large population centres in close proximity to livestock facilities<sup>5</sup>, making the implementation of BMPs less likely<sup>6</sup>.

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4. Canadian Pork Council (2002) and Caldwell and Toombs (1999). For more details on regulations, codes of practice and Beneficial Management Practices related to livestock manure management, please refer to the Acts & Guidelines page on Agriculture and Agri-Food Canada *ManureNet* Web site: <http://res2.agr.ca/initiatives/manurenet/en/codes.html>.

5. This refers to environmental and public concerns regarding livestock operations that are in close proximity to large urban populations.

6. Canadian Pork Council (2002), Lafond et al. (1994).

## 2. Manure management plan

Hog producers that have developed formal manure management plans are expected to be more likely to implement BMPs for manure compared to producers who have not developed such plans.

## 3. Farm size

Farm size will influence the decisions a farmer makes regarding the management of manure. Intensive livestock operations are usually more highly regulated, and often incur public notice and concern.

Due to the large volume of hog manure produced, large farms must have adequate manure storage facilities, formal plans developed for the treatment and application of manure, and methods to limit odour. Medium and small farms must also consider appropriate facilities for the storage and treatment of manure, but they may be under relatively fewer restrictions.

As well, operators of larger farms are generally perceived as being financially better off. Smaller farms are often operating under tighter margins, making the investments required for sound environmental and manure management practices more difficult.

It is expected that larger farms would have a greater likelihood of implementing BMPs due to economies of scale. As a farm increases in size, the average cost per unit of implementing BMPs decreases, leading to higher implementation, up to a point where increases in farm size no longer influence BMPs implementation (Hindsley 2002).



Three measures of size were used in the model: the number of pigs, the value of land and buildings and the gross farm receipts.<sup>7</sup>

#### 4. Specialization<sup>8</sup>

Each farm was classified according to the predominant type of production. Potential farm receipts were estimated from the inventories of crops and livestock reported on the Census of Agriculture questionnaire. Farm type was determined based on the product, or group of products, that makes up the majority of the estimated receipts.

Farms specialized in raising pigs are expected to implement BMPs at a higher rate.

#### 5. Operating arrangement<sup>9</sup>

Hired managers on incorporated non-family farms have an obligation to shareholders to ensure that environmental regulations are complied with in order to avoid prosecution, lawsuits or other forms of dispute (Kehrig 2002, Carter and Owen 2000). On the other hand, it may also be argued that operators on family farms tend to be better stewards of their land because their actions often directly affect their quality of life and their environment. Notwithstanding, non-family incorporated farms are expected to be more likely than other types of farms to implement BMPs.

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7. Gross farm receipts is the total gross farm receipts of the operation in 2000 (calendar year) or for the last complete accounting (fiscal) year. It includes receipts from all agricultural products sold, marketing board payments received, program and rebate payments, dividends received from co-operatives, custom work and all other farm receipts. It excludes receipts from the sale of capital item and from the sale of any goods bought only for resale.

8. Specialized hog farms are farms on which the derived sales of pigs make up 51% or more of the total derived farm sales.

9. Farm organization types were grouped in two categories: family farms or non-family farms. Family farms include sole proprietorship, partnership and family corporation organizations. Non-family farms are non-family corporations.

## 6. Livestock concentration

Traditionally, hog farms have purchased most of their feed grains and have been able to operate on very little land. In some provinces, more stringent provincial or municipal regulations and producer codes of practices have encouraged farmers to acquire land or set up agreements with neighbours to make more land available for manure utilisation.

Two variables were used to capture the effect of the regional concentration of livestock on the implementation of BMPs. The first variable measured hog farming intensity by the number of pigs per acre of tillable land<sup>10</sup>. The second variable was the farmland acreage.

It is expected that hog intensity will increase the likelihood of implementing BMPs. Farms with a large farmland base are expected to be less likely to implement BMPs as there might be fewer close neighbours expressing their concerns compared to farms located in more densely populated rural areas.

## 7. Number of operators

Having more than one operator making decisions on a farm adds experience and knowledge to farm management decision-making. Experience and knowledge are two factors that have been shown to affect the adoption behaviour of agricultural producers (Nowak 1992, Fletcher and Seitz 1986). The presence of multiple operators also often indicates succession planning for the farm. In particular, senior or older farmers may choose to include BMPs into a long-term farming strategy if there is another operator present to ensure the continuity of the farm operation.

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10. Includes cropland, summerfallow and pasture.

## 8. Age of first operator<sup>11</sup>

Age can be a factor in determining farmers' choices of farming practices. As operators age, they gain experience and knowledge that may increase their willingness to adopt new farming practices and technologies. However, for older farmers approaching retirement, the likelihood of adoption would decrease (Potter and Lobley 1992). They tend to be more risk-averse than younger farmers and do not usually want to change their methods or technology or make substantive investments during their remaining years of production. These older farmers may also be less aware of the latest trends in agricultural production practices (Kehrig 2002). It is expected that younger farmers will be more likely to implement BMPs than farmers approaching retirement age.

## 9. Work off-farm by the first operator<sup>12</sup>

Farm operators who work off their farms divide their time between managing farming operations and working at other employment. Our hypothesis is that farms with the main operator working off-farm would be less likely to have BMPs than farms with the main operator working full time on the operation.

## 10. Gender<sup>13</sup>

We have no *a priori* for the implementation of BMPs by the operator's gender for this study. However, it is interesting to note that a study of BMPs implementation on crop operations in Saskatchewan found that women on farms were primarily concerned with the health of their family and may care more about the environment and water quality than men, who tend to be preoccupied with production issues (Kehrig 2002).

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11. Age of operator is the age of the first operator as of May 15<sup>th</sup>, 2001.

12. Work off-farm is the average number of hours per week the operator contributed to non-farm work.

13. Sex of operator is the gender of the first operator.

## Data sources

The sources of data are the 2001 Farm Environmental Management Survey (FEMS) and the 2001 Census of Agriculture. FEMS is a survey developed and administered by the Agriculture Division of Statistics Canada on behalf of Agriculture and Agri-Food Canada, to gather information on farm environmental management practices such as manure management<sup>14</sup>.

The target population of the 2001 FEMS consisted of all active farms in Canada with gross farm receipts of \$10,000 or more<sup>15</sup> excluding the Yukon, Northwest Territories and Nunavut. The population was defined by the Agriculture Division's Farm Register, which was based on the 1996 Census of Agriculture. Due to data collection constraints, farms on Indian reserves, institutional farms, community pastures, and multi-holding companies were also excluded from the survey. Farms were sampled without replacement in each stratum formed using the watershed and farm type information. The total sample size was set at 22,600 farms. The survey was conducted in March 2002. About 76% or 16,053 questionnaires were completed.

For the purpose of analysis, records from FEMS have been linked to records from the 2001 Census of Agriculture in order to make use of a richer set of information. Three farms that reported more than one answer to the BMPs for manure question were discarded. From this linked file, the farms reporting pigs (a subsample of 1,072 farms) were retained for analysis. After extrapolating this sample to the population, these records represented 11,904 hog farms, about 90% of farms reporting pigs in the 2001 Census of Agriculture with gross farm receipts greater than \$10,000.

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14. Readers interested in the survey methodology for FEMS should refer to Statistics Canada Internet site: <http://www.statcan.ca/bsolc/english/bsolc?catno=21-021-MWE>.

15. This criterion was used in the sampling design. However, some farms may have reported gross farm receipts of less than \$10,000 in the year the survey was conducted.

## Limitations

Due to the limited number of observations, farm operators reporting they had fully implemented BMPs were grouped with those reporting they had partially implemented BMPs. Farm operators reporting that BMPs were not available in their region, that BMPs were not relevant for their operation or that they were unfamiliar with BMPs were considered as not having implemented BMPs<sup>16</sup>. Grouping farmers who have fully implemented BMPs with those who had only “partially” implemented BMPs is not ideal. For instance, a farmer might have answered “partially implemented” if he had started to develop a plan for a BMP without taking any action. He or she does not achieve the same outcomes as a farmer who had implemented several BMPs. However, it was considered advantageous to include the farm that partially implemented BMPs for data consideration.

Since the data is based only on survey information, there is no ground-truthing as to what BMPs were actually implemented, and to what degree. More accurate results would have been collected if the data had been collected from the evaluation of a BMP incentive program, farm visits, or peer review of BMPs implementation. BMPs can mean different things to different people, and can be implemented to different degrees, in different ways and under different geographic and climatic conditions.

Furthermore, the survey was not designed to measure the impacts or environmental outcomes from implementing a particular BMP which are highly dependent upon site-specific conditions. Measurements of changes in water quality (nutrients, pathogens) or air quality

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16. Respondents were asked the following question: “To what extent have you implemented Beneficial Management Practices (BMP)(or Best Management Practices) for manure management” and they had to check applicable choices “1. Fully implemented, 2. Partially implemented, 3. Not available in my region, 4. Not relevant for my operation or 5. Unfamiliar with the BMP for my region”.

(odours), decreases in odour intensity, reductions in pathogen counts, or increase nutrient use efficiencies were beyond the scope of the FEMS.

Other factors that would be expected to have some impact on the decision made by farmers to participate in BMPs such as level of education, years of experience, level of environmental concern, and participation in government programs or membership to producers' organizations, are not available from the data sources, and were assumed to be unexplained factors in the logistic regression model.

Finally, the question pertaining to BMPs do not specify animal type. This analysis included all farms raising pigs. Some of these farms could be diversified and they could have also raised poultry and/or other livestock. Thus, the extent of implementation of BMPs may have applied to hog manure but also to poultry and/or non-hog livestock manure. Readers are invited to use caution when interpreting the results.

## **Results**

### **Descriptive statistics**

The weighted proportions of farms that implemented BMPs were established based on the 2001 FEMS. They are presented in Table 1.

Of the 11,904 operations raising pigs in Canada, half of them had implemented BMPs in 2001. Quebec had the highest proportion of hog producers (88.9%) implementing BMPs. Saskatchewan and Alberta had the lowest proportions (19.6% and 31.6% respectively).

About 86% of farms having a formal manure management plan required by government regulations had implemented BMPs, while only 36% of farms with no formal plan had BMPs.

Farms raising a greater number of pigs had implemented BMPs at a higher rate than smaller operations. About 79% of operations with 5,000 or more head implemented BMPs compared to less than 50% for operations with less than 500 head.

Similarly, over 62% of farms valued at \$1,000,000 and more had implemented BMPs, while the proportion was much smaller (30.8%) for farms valued at less than \$250,000.

Over 64.4% of farms with annual gross farm receipts of \$250,000 or more had implemented BMPs, compared to less than 47% for farms in smaller farm receipts groups.

Seventy percent of non-family incorporated farms had implemented BMPs in 2001, compared to 49.2% for farms with other types of operating arrangements.

The relationship between BMPs implementation and farming intensity based on farmland area available is not as clear. Fifty seven percent of farms with less than 70 acres had implemented BMPs, while this proportion was between 45% and 49% for farms with 1,600 acres or more. Only 38.8% of medium area farms (760 to 1,599 acres) had implemented BMPs.

About 68% of more intensive farms (i.e., with two pigs or more per tillable acre) had implemented BMPs, compared to less than 50% of BMPs implementation for less intensive farms (less than two pigs per tillable acre).

About 55% of farms with more than one operator had BMPs, compared to 45.2% for farms with only one operator.

The proportion of BMPs implementation was about the same for all age groups (close to 50%).

Farms in which the first operator was not working off-farm had implemented BMPs to a greater extent. Almost 56% of these farms had implemented BMPs, compared to 36.6% for farms that had the main operator having more than 20 hours of off-farm work per week.

Three-quarters of farms having a female as the main operator reported having implemented BMPs, compared to half of farms with a male as the main operator.



**Table 1: Implementation of Beneficial Management Practices for manure management on hog operations, 2001**

| <b>Variables</b>                             |                             | <b>Sample size</b> | <b>Weighted sum</b> | <b>% of farms with BMPs</b> | <b>Sampling error (%)</b> | <b>(*)</b> |
|--|-----------------------------|--------------------|---------------------|-----------------------------|---------------------------|------------|
| <b>All farms</b> <sup>1</sup>                |                             | 1,072              | 11,904              | 50.2                        | 1.6                       |            |
| <b>Region</b>                                | Atlantic <sup>2</sup>       | 78                 | 408                 | 44.4                        | 6.2                       | B,C        |
|  | Quebec                      | 189                | 2,605               | 88.9                        | 2.2                       | A          |
|  | Ontario                     | 263                | 3,677               | 46.7                        | 3.0                       | B          |
|  | Manitoba                    | 131                | 1,263               | 48.9                        | 4.8                       | B          |
|  | Saskatchewan                | 129                | 1,296               | 19.6                        | 3.8                       | D          |
|  | Alberta                     | 213                | 2,330               | 31.6                        | 3.2                       | C,D        |
|  | British Columbia            | 69                 | 323                 | 45.9                        | 7.7                       | B,C        |
| <b>Formal manure management plan</b>         | Required by government      | 146                | 1,824               | 86.2                        | 2.8                       | A          |
|  | As part of NMP <sup>3</sup> | 144                | 1,612               | 75.4                        | 3.7                       | A          |
|  | Concerns environment        | 52                 | 611                 | 73.9                        | 6.3                       | A          |
|  | No formal plan              | 680                | 7,317               | 36.0                        | 1.9                       | B          |
|  | Missing/DKN <sup>4</sup>    | 50                 | 540                 | 17.7                        | 5.9                       | C          |
| <b>Value of land and buildings (\$)</b>      | less than 250,000           | 225                | 2,516               | 30.8                        | 3.2                       | A          |
|  | 250,000-999,999             | 551                | 6,184               | 50.3                        | 2.2                       | B          |
|  | 1,000,000-1,999,999         | 166                | 1,843               | 62.2                        | 3.9                       | B,C        |
|  | 2,000,000 or more           | 130                | 1,360               | 68.6                        | 4.3                       | C          |
| <b>Number of pigs</b>                        | 1-99                        | 331                | 3,974               | 26.4                        | 2.5                       | A          |
|  | 100-499                     | 239                | 2,681               | 45.4                        | 3.4                       | B          |
|  | 500-999                     | 164                | 1,750               | 69.2                        | 3.7                       | C          |
|  | 1,000-4,999                 | 299                | 3,204               | 70.6                        | 2.7                       | C          |
|  | 5,000 or more               | 39                 | 293                 | 78.8                        | 7.3                       | C          |
| <b>Gross farm receipts (\$) <sup>5</sup></b> | 0-10,000                    | 45                 | 415                 | 33.6                        | 7.6                       | A,B        |
|  | 10,000-49,999               | 195                | 2,289               | 25.3                        | 3.2                       | B          |
|  | 50,000-249,999              | 387                | 4,455               | 46.5                        | 2.6                       | A          |
|  | 250,000-499,999             | 209                | 2,316               | 69.7                        | 3.3                       | C          |
|  | 500,000 or more             | 236                | 2,429               | 64.4                        | 3.3                       | C          |
| <b>Farmland area (acres)</b>                 | less than 70                | 153                | 1,425               | 57.0                        | 4.4                       | A          |
|  | 70-399                      | 488                | 5,700               | 52.1                        | 2.3                       | A          |
|  | 400-759                     | 175                | 1,947               | 50.8                        | 3.9                       | A,B        |
|  | 760-1,599                   | 138                | 1,602               | 38.8                        | 4.3                       | B          |
|  | 1,600-2,879                 | 55                 | 598                 | 45.3                        | 7.2                       | A,B        |
|  | 2,880 or more               | 63                 | 632                 | 48.8                        | 6.8                       | A,B        |

**Table 1: Implementation of Beneficial Management Practices for manure management on hog operations, 2001 (continued)**

| Variables   |                          | Sample size | Weighted sum | % of farms with BMPs | Sampling error (%) | (*) |
|---|--------------------------|-------------|--------------|----------------------|--------------------|-----|
| <b>Farming intensity (pigs per tillable acre)</b> | less than 0.1            | 237         | 3,038        | 28.1                 | 2.9                | A   |
|   | 0.1-0.49                 | 148         | 1,678        | 33.1                 | 4.0                | A,B |
|   | 0.5-0.99                 | 108         | 948          | 51.0                 | 5.3                | B   |
|   | 1.0-1.99                 | 107         | 989          | 48.7                 | 5.3                | B   |
|   | 2.0-4.99                 | 175         | 2,020        | 68.6                 | 3.6                | C   |
|   | 5.0 or more              | 297         | 3,230        | 68.4                 | 2.8                | C   |
| <b>Specialization</b> <sup>6</sup>                | Non-specialized          | 608         | 6,052        | 65.0                 | 2.0                | A   |
|   | Specialized hog farm     | 464         | 5,852        | 34.8                 | 2.2                | B   |
| <b>Operating arrangement</b>                      | Other types <sup>7</sup> | 1018        | 11,347       | 49.2                 | 1.6                | A   |
|   | Non-family corporation   | 54          | 557          | 70.3                 | 6.6                | B   |
| <b>Age</b> <sup>8</sup>                           | 18-25                    | 4           | 57           | 48.5                 | 24.1               | A,B |
|   | 26-35                    | 99          | 1,128        | 48.6                 | 5.2                | A,B |
|   | 36-45                    | 355         | 3,870        | 50.7                 | 2.8                | A   |
|   | 46-55                    | 348         | 3,918        | 53.4                 | 2.8                | A   |
|   | 56-65                    | 193         | 2,101        | 51.3                 | 3.8                | A   |
|   | Over 65                  | 73          | 829          | 31.7                 | 5.6                | A,B |
| <b>Number of operators</b>                        | One                      | 556         | 6,023        | 45.2                 | 2.2                | A   |
|   | Two or more              | 516         | 5,881        | 55.2                 | 2.3                | B   |
| <b>Work off-farm</b>                              | No off-farm work         | 751         | 8,380        | 55.9                 | 1.9                | A   |
|   | Yes                      | 321         | 3,523        | 36.6                 | 2.8                | B   |
| <b>Gender 1st operator</b>                        | Male                     | 1035        | 11,515       | 49.3                 | 1.6                | A   |
|   | Female                   | 37          | 389          | 75.4                 | 7.2                | B   |

- Notes:**
1. Farms that reported having at least one hog on their agricultural operation on May 15th, 2001.
  2. Includes Newfoundland and Labrador, Prince Edward Island, Nova Scotia and New Brunswick.
  3. As part of a nutrient management plan.
  4. Respondents left this question unanswered.
  5. Total gross farm receipts of the operation in 2000 (calendar year) or for the last complete accounting (fiscal) year.
  6. Specialized hog farms are farms on which the derived sales of pigs make up 51% or more of the total derived farm sales.
  7. Includes sole proprietorship, partnership and family corporation organizations.
  8. Age of operator as of May 15th, 2001.
- (\*) Categories with the same letter were not statistically different at the 95% level.

**Sources:** Statistics Canada, 2001 Farm Environmental Management Survey and 2001 Census of Agriculture.

## Variables retained in the final model

Table 2 presents the significance of the variables retained in the final model<sup>17</sup> showing the Wald chi-square and the P value of Wald chi-square results.

The first test (overall model) rejects the null hypothesis that the probability of implementing BMPs is constant and at a value of 0, 0.5 or 1. The null hypothesis that none of the explanatory variables are related to BMPs (model minus the intercept) is also rejected. We therefore accept the alternate hypothesis that the regression coefficients, except the intercept, are not all equal to 0.

The tests presented in Table 2 indicate which variables, conditional on all other variables in the model, have statistically significant effects on the implementation of BMPs. The region, having a formal manure management plan, value of land and buildings, number of pigs, gross farm receipts, farming intensity, operating arrangement and gender all had significant effects on the implementation of BMPs. Farmland area<sup>18</sup> and age were not statistically significant and thus, they did not have an effect on BMPs implementation.

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17. Work off-farm, number of operators and specialization were excluded from the final model as they added no explanatory value to the model.

18. We acknowledge that manure management plans are not independent of the number of pigs. Similarly, number of pigs and farm revenues, value of land and buildings and farmland area are correlated. All these variables were left in the model as they contributed to its explanatory power. Farmland area and age were left in as they indirectly affect the other variables. The presence of multicollinearity might explain the uneven level of significance of the effect of farmland area and farming intensity.

**Table 2: Analysis of variance for the implementation of Beneficial Management Practices for manure management on hog operations, 2001**

| <b>Contrast</b>                    | <b>Degree of freedom for the F tests</b> | <b>Wald chi-square</b> | <b>P value Wald chi-square</b> | <b>(*)</b> |
|------------------------------------|--|------------------------|--------------------------------|------------|
| <b>Overall model</b>               | 39                                       | 285.77                 | 0.0000                         | ***        |
| <b>Model minus intercept</b>       | 38                                       | 284.22                 | 0.0000                         | ***        |
| <b>Intercept</b>                   | -  | -                      | -                              |            |
| <b>Region</b>                      | 6  | 72.53                  | 0.0000                         | ***        |
| <b>Manure management plan</b>      | 4  | 39.15                  | 0.0000                         | ***        |
| <b>Value of land and buildings</b> | 3  | 11.37                  | 0.0099                         | ***        |
| <b>Number of pigs</b>              | 4  | 10.71                  | 0.0300                         | **         |
| <b>Gross farms receipts</b>        | 4  | 11.32                  | 0.0232                         | **         |
| <b>Land</b>                        | 5  | 4.75                   | 0.4477                         |            |
| <b>Farming intensity</b>           | 5  | 11.20                  | 0.0475                         | **         |
| <b>Operating arrangement</b>       | 1  | 4.33                   | 0.0374                         | **         |
| <b>Age</b>                         | 5  | 6.91                   | 0.2271                         |            |
| <b>Gender 1st operator</b>         | 1  | 8.90                   | 0.0029                         | ***        |

**Model information**

|  |          |
|--|----------|
| -2 *normalized Log-Likelihood Full Model | 1,071.43 |
| Approximate Chi-square (-2*Log-L ratio)  | 414.67   |
| R-Square                                 | 32.07%   |
| Degrees of freedom                       | 38       |

**Notes:** Similar results were produced using the Adjusted Wald F, Satterthwaite adjusted chi-square and F statistics. The R<sup>2</sup> statistic provides an indication of the logit model's explanatory power.  
 (\*) \*\*\*Significant at the 0.01 level, \*\*Significant at the 0.05 level.

**Sources:** Statistics Canada, 2001 Farm Environmental Management Survey and 2001 Census of Agriculture.

## Odd ratios

The likelihood of implementing BMPs was measured in terms of odds<sup>19</sup>. The odds ratios indicate the relative odds of implementing BMPs for a given profile (or category) compared to a reference profile after controlling for the effects of all other variables in the model. Odd ratios are presented in Table 3. Odd ratios were estimated with a confidence limit of 95%.

Hog producers in all provinces were less likely to have implemented BMPs for manure management than their counterparts in Quebec. For example, the odds of having BMPs for hog producers in the Atlantic Provinces were six times smaller (1/0.17) than the odds of Quebec's producers.

Being a hog producer in Ontario made the odds of having BMPs almost one-eighth of that for a producer in Quebec. In Saskatchewan, the odds were one-twentieth of the odds of the Quebec's producers.

Farms having a formal manure management plan had greater likelihoods of implementing BMPs compared to farms with no formal plan. The odds of farms with a formal plan as required by regulation or as part of a nutrient management plan were more than two times the odds of a farm with no formal plan. Farms with a plan developed as concern for the environment had the odds of implementing BMPs almost five times larger than the odds of farms with no plan.

A farm valued at less than \$250,000 had odds of implementing BMPs one-fourth of that for a farm valued at \$2,000,000 or more. The odds of implementing BMPs for medium-size farms, valued between \$250,000 and \$999,999, were two-fifth of the odds of the largest farms.

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19. Interpretation of results in terms of odd ratios is easier than the model estimated logit coefficients. These coefficients are presented in Table A1 in Appendix.

Farms with less than 500 pigs had lower odds of implementing BMPs than farms with 5,000 head or more. The odds for farms with 100 to 499 head were almost one-third the odds of larger farms and one-seventh of that for farms with less than 100 pigs.

In terms of gross receipts, farms with gross farm receipts between \$250,000 and \$499,999 were the only group of farms that had significantly higher odds of having implemented BMPs than larger farms with gross farm receipts of \$500,000 or more.

The odds of implementing BMPs for non-family corporation farms were 2.5 times greater than the odds for farms with other types of operating arrangements.

Finally, farms with a female as the main operator had odds of implementing BMPs 4.61 larger than the odds of farms with a male as the main operator.

**Table 3: Odds ratio of Beneficial Management Practices for manure management on hog operations <sup>1</sup>, 2001**

| Independent variables and effects            | Odds Ratio (OR) | Lower 95% Limit OR | Upper 95% Limit OR | (*) |
|--|-----------------|--------------------|--------------------|-----|
| <b>Intercept</b>                             | 6.35            | 1.52               | 26.58              |     |
| <b>Region</b>                                |                 |                    |                    |     |
| Atlantic <sup>2</sup>                        | 0.17            | 0.07               | 0.38               | *** |
| Quebec †                                     | 1.00            | 1.00               | 1.00               |     |
| Ontario                                      | 0.13            | 0.07               | 0.23               | *** |
| Manitoba                                     | 0.15            | 0.07               | 0.30               | *** |
| Saskatchewan                                 | 0.05            | 0.02               | 0.12               | *** |
| Alberta                                      | 0.08            | 0.04               | 0.15               | *** |
| British Columbia                             | 0.24            | 0.09               | 0.59               | *** |
| <b>Formal manure management plan</b>         |                 |                    |                    |     |
| Required by government                       | 2.05            | 1.10               | 3.84               | **  |
| As part of NMP <sup>3</sup>                  | 2.65            | 1.63               | 4.31               | *** |
| Concerns environment                         | 4.52            | 2.26               | 9.04               | *** |
| No formal plan †                             | 1.00            | 1.00               | 1.00               |     |
| Missing/DKN <sup>4</sup>                     | 0.34            | 0.14               | 0.85               | **  |
| <b>Value of land and buildings (\$)</b>      |                 |                    |                    |     |
| less than 250,000                            | 0.24            | 0.10               | 0.57               | *** |
| 250,000-999,999                              | 0.42            | 0.21               | 0.87               | **  |
| 1,000,000-1,999,999                          | 0.59            | 0.30               | 1.16               |     |
| 2,000,000 or more †                          | 1.00            | 1.00               | 1.00               |     |
| <b>Number of pigs</b>                        |                 |                    |                    |     |
| 1-99   | 0.15            | 0.04               | 0.63               | *** |
| 100-499                                      | 0.28            | 0.08               | 0.90               | **  |
| 500-999                                      | 0.51            | 0.17               | 1.57               |     |
| 1,000-4,999                                  | 0.41            | 0.15               | 1.10               | *   |
| 5,000 or more †                              | 1.00            | 1.00               | 1.00               |     |
| <b>Gross farm receipts (\$) <sup>5</sup></b> |                 |                    |                    |     |
| 0-10,000                                     | 2.83            | 0.98               | 8.21               | *   |
| 10,000-49,999                                | 1.34            | 0.64               | 2.82               |     |
| 50,000-249,999                               | 1.79            | 0.99               | 3.24               | *   |
| 250,000-499,999                              | 2.26            | 1.29               | 3.94               | *** |
| 500,000 or more †                            | 1.00            | 1.00               | 1.00               |     |

**Table 3: Odds ratio of Beneficial Management Practices for manure management on hog operations <sup>1</sup>, 2001 (continued)**

| Independent variables and effects                 | Odds Ratio (OR) | Lower 95% Limit OR | Upper 95% Limit OR (*) |
|---|-----------------|--------------------|------------------------|
| <b>Farmland area (acres)</b>                      |                 |                    |                        |
| less than 70                                      | 1.96            | 0.60               | 6.39                   |
| 70-399  | 1.81            | 0.67               | 4.91                   |
| 400-759   | 2.27            | 0.91               | 5.63 *                 |
| 760-1,599   | 2.00            | 0.85               | 4.72                   |
| 1,600-2,879                                       | 2.28            | 0.90               | 5.77 *                 |
| 2,880 or more †                                   | 1.00            | 1.00               | 1.00                   |
| <b>Farming intensity (pigs per tillable acre)</b> |                 |                    |                        |
| less than 0.1                                     | 2.11            | 0.67               | 6.61                   |
| 0.1-0.49  | 1.12            | 0.47               | 2.69                   |
| 0.5-0.99  | 1.56            | 0.72               | 3.40                   |
| 1.0-1.99  | 0.95            | 0.47               | 1.90                   |
| 2.0-4.99  | 1.91            | 1.06               | 3.42 **                |
| 5.0 or more †                                     | 1.00            | 1.00               | 1.00                   |
| <b>Operating arrangement</b>                      |                 |                    |                        |
| Other types <sup>6</sup> †                        | 1.00            | 1.00               | 1.00                   |
| Non-family corporation                            | 2.50            | 1.05               | 5.93 **                |
| <b>Age <sup>7</sup></b>                           |                 |                    |                        |
| 18-25   | 0.35            | 0.08               | 1.57                   |
| 26-35   | 1.58            | 0.70               | 3.57                   |
| 36-45   | 1.25            | 0.63               | 2.49                   |
| 46-55   | 1.42            | 0.70               | 2.85                   |
| 56-65   | 1.72            | 0.82               | 3.58                   |
| Over 65 †   | 1.00            | 1.00               | 1.00                   |
| <b>Gender 1st operator</b>                        |                 |                    |                        |
| Male †  | 1.00            | 1.00               | 1.00                   |
| Female  | 4.61            | 1.69               | 12.57 ***              |

**Notes:** † Reference category

1. Farms that reported having at least one hog on their agricultural operation on May 15th, 2001.
  2. Includes Newfoundland and Labrador, Prince Edward Island, Nova Scotia and New Brunswick.
  3. Part of a nutrient management plan.
  4. Respondents left this question unanswered.
  5. Total gross farm receipts of the operation in 2000 (calendar year) or for the last complete accounting (fiscal) year.
  6. Includes sole proprietorship, partnership and family corporation organizations.
  7. Age of operator as of May 15th, 2001.
- (\*) \*\*\*Significant at the 0.01 level, \*\*Significant at the 0.05 level, \*Significant at the 0.10 level in Appendix Table A1.

**Sources:** Statistics Canada, 2001 Farm Environmental Management Survey and 2001 Census of Agriculture.



## Discussion

Results indicate that in a province where more comprehensive and stringent regulations for livestock operations exist, hog farmers were more likely to have implemented BMPs. Quebec legislation includes several features that address the problem of pollution from livestock operations. For example: liquid manure storage facilities must be leak-proof (Intensive livestock operations are required to use concrete liners); have a minimum capacity of 250 days of manure production and prevent overflow; be located 300 m from a spring or well or 150 m from the nearest water body; and have detailed, documented plans and agreements for the transport, treatment and application of manure.

In Ontario, the approach has moved toward a more regulatory framework since 2001. Before then, the provincial policy approach included more governance by municipal by-laws. The Prairie Provinces have adopted public and municipal processes to promote implementation of manure management practices<sup>4</sup>. BMPs for Saskatchewan and Alberta are mainly voluntary, and generally presented as guidelines for farm management.

Another interesting result is the positive influence of the development of formal manure management plans on the implementation of BMPs. Due to the large prevalence of BMPs and mandatory manure management plans in Quebec, it was difficult to assess if this result would hold for other regions outside Quebec. No interaction terms (or profile resulting from the combination of more than one variable e.g. comparing large farms in Quebec to farms in each size group in other provinces) were evaluated due to data limitations. One approach would be to exclude Quebec and run the model with the other provinces. The inclusion of interaction effects was beyond the scope of this article, and may need to be investigated in future research.

It is clear that size has an impact on the implementation of BMPs. Larger operations were more likely to implement BMPs than medium or small operations. Due to the large volume of hog manure produced, it is likely that regions target larger farms first via regulations or voluntary codes of practice. Medium and small farms must also consider appropriate BMPs for manure but they are more likely to need assistance to implement BMPs.

Interestingly, the age of the main operator was not a factor influencing the implementation of BMPs, while gender was. This suggests that the design of any type of BMPs promotion/education program should consider gender in their plan to reach specific socio-demographic groups.

## **Summary and conclusions**

The tendency for livestock production to concentrate and expand has been a particular issue in many parts of Canada. This has increased environmental and health concerns about the storage, use, and treatment of manure.

BMPs were set forth by governments, businesses, academics and local communities. They were designed to provide proven technologies and information based on research and extensive experience and to address the need for comprehensive guidelines for manure management.

In this study, the location of farms (province) was found to have a significant influence on the decision made by hog producers to implement BMPs. Hog farms in Quebec were found to be more likely to implement BMPs than farms in any other province.

This location effect may be attributed to regional differences in legal and policy frameworks, the relative importance of different commodity sectors, climate and soil conditions, population densities and demographics, and public perceptions of hog operations and concerns over environmental and health issues.

Farms having a formal manure management plan were also more likely to implement BMPs compared to farms with no formal plan.

Farm size was another important factor. Larger hog operations were more likely to have implemented BMPs than medium or small hog farms, as they are often more regulated and increasingly required to implement BMPs.

Interestingly, the age of the main operator was not a factor influencing the adoption of BMPs, while gender was. Farms with a female as the main operator were more likely to implement BMPs than farms with a male as the main operator.

This study looked only at hog operations and the implementation of BMPs for manure management. Due to the large discrepancy in the implementation of BMPs and regulatory framework between Quebec and the other provinces, it is not clear whether the results would hold if Quebec was treated in a separate model. No interaction terms or combination of effects were used due to data limitations. One approach would be to exclude Quebec and run the model with the other provinces. Such analysis was beyond the scope of this article. The issue will need to be investigated in future research.

## Appendix A

**Table A1. Estimated logit coefficients for the implementation of Beneficial Management Practices for manure management on hog operations<sup>1</sup>, Canada, 2001**

| Independent variables and effects     |                             | Beta coefficients | Betas sampling error | Design effect | T-statistic | P Value | (*) |
|---------------------------------------|-----------------------------|-------------------|----------------------|---------------|-------------|---------|-----|
| Intercept                             |                             | 1.85              | 0.73                 | 0.85          | 2.5324      | 0.0113  | **  |
| Region                                | Atlantic <sup>2</sup>       | -1.80             | 0.42                 | 0.66          | -4.2267     | 0.0000  | *** |
|                                       | Quebec †                    |                   |                      |               |             |         |     |
|                                       | Ontario                     | -2.08             | 0.31                 | 1.02          | -6.6786     | 0.0000  | *** |
|                                       | Manitoba                    | -1.92             | 0.37                 | 0.95          | -5.1673     | 0.0000  | *** |
|                                       | Saskatchewan                | -2.96             | 0.42                 | 0.92          | -6.9838     | 0.0000  | *** |
|                                       | Alberta                     | -2.58             | 0.33                 | 0.93          | -7.7242     | 0.0000  | *** |
|                                       | British Columbia            | -1.45             | 0.47                 | 0.77          | -3.0725     | 0.0021  | *** |
| Formal manure management plan         | Required by government      | 0.72              | 0.32                 | 0.99          | 2.2555      | 0.0241  | **  |
|                                       | As part of NMP <sup>3</sup> | 0.97              | 0.25                 | 0.95          | 3.9146      | 0.0001  | *** |
|                                       | Concerns environment        | 1.51              | 0.35                 | 0.98          | 4.2722      | 0.0000  | *** |
|                                       | No formal plan †            |                   |                      |               |             |         |     |
|                                       | Missing/DKN <sup>4</sup>    | -1.07             | 0.46                 | 1.01          | -2.3103     | 0.0209  | **  |
| Value of land and buildings (\$)      | less than 250,000           | -1.43             | 0.44                 | 0.96          | -3.2270     | 0.0013  | *** |
|                                       | 250,000-999,999             | -0.86             | 0.37                 | 0.96          | -2.3286     | 0.0199  | **  |
|                                       | 1,000,000-1,999,999         | -0.53             | 0.35                 | 0.97          | -1.5240     | 0.1275  |     |
|                                       | 2,000,000 or more †         |                   |                      |               |             |         |     |
| Number of pigs                        | 1-99                        | -1.88             | 0.73                 | 0.90          | -2.5828     | 0.0098  | *** |
|                                       | 100-499                     | -1.29             | 0.61                 | 0.88          | -2.1278     | 0.0334  | **  |
|                                       | 500-999                     | -0.67             | 0.57                 | 0.86          | -1.1734     | 0.2407  |     |
|                                       | 1,000-4,999                 | -0.89             | 0.50                 | 0.83          | -1.7712     | 0.0765  | *   |
|                                       | 5,000 or more †             |                   |                      |               |             |         |     |
| Gross farm receipts (\$) <sup>5</sup> | 0-10,000                    | 1.04              | 0.54                 | 0.90          | 1.9208      | 0.0548  | *   |
|                                       | 10,000-49,999               | 0.29              | 0.38                 | 0.96          | 0.7727      | 0.4397  |     |
|                                       | 50,000-249,999              | 0.58              | 0.30                 | 0.95          | 1.9180      | 0.0551  | *   |
|                                       | 250,000-499,999             | 0.81              | 0.29                 | 0.92          | 2.8541      | 0.0043  | *** |
|                                       | 500,000 or more †           |                   |                      |               |             |         |     |

**Table A1. Estimated logit coefficients for the implementation of Beneficial Management Practices for manure management on hog operations, Canada, 2001 (continued)**

| Independent variables and effects                 |                          | Beta coefficients | Betas sampling error | Design effect | T-statistic | P Value | (*) |
|---|--------------------------|-------------------|----------------------|---------------|-------------|---------|-----|
| <b>Farmland area (acres)</b>                      | less than 70             | 0.68              | 0.60                 | 0.96          | 1.1215      | 0.2621  |     |
|   | 70-399                   | 0.59              | 0.51                 | 0.97          | 1.1631      | 0.2448  |     |
|   | 400-759                  | 0.82              | 0.46                 | 0.98          | 1.7613      | 0.0782  | *   |
|   | 760-1,599                | 0.69              | 0.44                 | 0.98          | 1.5868      | 0.1126  |     |
|   | 1,600-2,879              | 0.82              | 0.47                 | 0.97          | 1.7332      | 0.0831  | *   |
|   | 2,880 or more            | †                 |                      |               |             |         |     |
| <b>Farming intensity (pigs per tillable acre)</b> | less than 0.1            | 0.75              | 0.58                 | 0.97          | 1.2776      | 0.2014  |     |
|   | 0.1-0.49                 | 0.11              | 0.45                 | 0.96          | 0.2536      | 0.7998  |     |
|   | 0.5-0.99                 | 0.45              | 0.40                 | 0.93          | 1.1201      | 0.2627  |     |
|   | 1.0-1.99                 | -0.05             | 0.36                 | 0.92          | -0.1489     | 0.8816  |     |
|   | 2.0-4.99                 | 0.65              | 0.30                 | 0.97          | 2.1704      | 0.0300  | **  |
|   | 5.0 or more              | †                 |                      |               |             |         |     |
| <b>Operating arrangement</b>                      | Other types <sup>6</sup> | †                 |                      |               |             |         |     |
|   | Non-family corporation   | 0.92              | 0.44                 | 0.93          | 2.0812      | 0.0374  | **  |
| <b>Age <sup>7</sup></b>                           | 18-25                    | -1.04             | 0.76                 | 1.04          | -1.3690     | 0.1710  |     |
|   | 26-35                    | 0.46              | 0.42                 | 0.97          | 1.1040      | 0.2696  |     |
|   | 36-45                    | 0.22              | 0.35                 | 0.97          | 0.6357      | 0.5250  |     |
|   | 46-55                    | 0.35              | 0.36                 | 0.98          | 0.9735      | 0.3303  |     |
|   | 56-65                    | 0.54              | 0.38                 | 0.97          | 1.4395      | 0.1500  |     |
|   | Over 65                  | †                 |                      |               |             |         |     |
| <b>Gender 1st operator</b>                        | Male                     | †                 |                      |               |             |         |     |
|   | Female                   | 1.53              | 0.51                 | 0.84          | 2.9832      | 0.0029  | *** |

**Notes:** † Reference category  
Coefficient variance estimates were calculated using the Taylor Series approximation method with SUDAAN statistical procedure using stratified without replacement sampling design. The t-statistic computed to test the null hypothesis that the estimated coefficient is equal to zero. Variables with negative logit coefficient indicate that the factor decreased the likelihood of BMPs implementations while variables with positive coefficients increased likelihood of implementation compared to the reference category.  
1. Farms that reported having at least one hog on their agricultural operation on May 15th, 2001.  
2. Includes Newfoundland and Labrador, Prince Edward Island, Nova Scotia and New Brunswick.  
3. Part of a nutrient management plan.  
4. Respondents left this question unanswered.  
5. Total gross farm receipts of the operation in 2000 (calendar year) or for the last complete accounting (fiscal) year.  
6. Includes sole proprietorship, partnership and family corporation organizations.  
7. Age of operator as of May 15th, 2001.  
(\*) All tests were conducted using a p-value of 0.05. \*\*\*Significant at the 0.01 level, \*\*Significant at the 0.05 level, \*Significant at the 0.10 level.

**Sources:** Statistics Canada, 2001 Farm Environmental Management Survey and 2001 Census of Agriculture.

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