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THE IMPORTANCE OF FARM AND OPERATOR CHARACTERISTICS
IN THE ADOPTION AND USE OF CONSERVATION TILLAGE IN
SOUTHWESTERN WISCONSIN

By

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I. Introduction

The environmental impacts of non-point pollution have become a major policy concern since the passage of the Water Pollution Control Act Amendments of 1972 (Chesters and Schierow, 1985). According to the 1977 National Water Quality Inventory, agricultural nonpoint pollution significantly affected water quality in more than two-thirds of all drainage basins in the U.S. (Environmental Protection Agency, 1984). This agricultural runoff results in increased sedimentation of the nation's streams and lakes, lake eutrophication, increased water treatment costs, and decreased groundwater quality (Braden and Uchtmann, 1985). These externalities provide the basis for public concern and intervention.

For more than half a century, the use of grassed waterways, terraces, contour plowing, strip cropping, and the raising of closely seeded crops have been used in Wisconsin to control soil erosion. Under the traditional farming system, farmers have used the moldboard plow as the primary tillage implement. Because of the degree to which the soil is lifted and turned over, the resulting field conditions are susceptible to wind and water erosion. Recently, new technologies have been developed which reduce soil erosion through the reduction in the number of primary tillage operations and the intensity of soil displacement. We can divide these reduced tillage systems into two general categories: (a) those that stir and mix the soil with the crop residues and (b) those that do not involve any general seedbed preparation. The use of chisel plows, primary tillage disc systems, and field cultivators fall in the first category while no-till systems fall into the second.

Given the social costs associated with soil erosion and nonpoint pollution, the question remains how state and Federal governments can most effectively motivate producers to adopt such soil conservation tillage practices. The least controversial would be the use of voluntary education programs. If such voluntary policies were enacted, it would be important to understand the relationship between producer characteristics and the adoption and use of these alternative tillage practices (Uchtmann and Seitz, 1979). For example, do farmers who face increased demands on their time because of an off-farm job, use reduced tillage practices at a different rate than full-time farmers in order to save field time? If a relationship between off-farm work and the use of time-saving cultivation practices can be established, then the increasing trend of off-farm employment and policies that assist in such activities may have an impact on the use of soil conservation practices.

In the present study we identify the important characteristics affecting the use of conservation tillage technologies for an important farming region in Wisconsin. In the report we first review previous studies of conservation tillage use and note how the model presented here extends earlier efforts. The data used in this study are presented in Section III. This is followed by the hypotheses and a theoretical model of conservation tillage adoption. Section V contains a description of the variables used in the empirical model. Section VI presents the results of the empirical model while the final section presents the policy implications of these results.

II. Previous Studies of the Adoption and the Extent of Use of Conservation Tillage

Over the last decade the use of alternatives to moldboard plow tillage practices as a means of controlling soil erosion and soil degradation has been the focus of considerable economic research. The issues addressed have included the role of operator, farm, land tenure and institutional characteristics on the use of these technologies. A distinction has been made between the adoption of such technologies, and the extent of their use (i.e., the level of conservation "effort"). Ervin and Ervin (1982) in their conceptual model of the farm level soil conservation process hypothesize a three staged decision making process: identifying the existence of an erosion problem, deciding whether or not to adopt conservation tillage practices given the recognition of such a problem, and determining the level of soil conservation effort having decided to adopt such technologies.

Previous studies have used a variety of techniques to measure both the adoption and the extent of use of soil conservation technologies, but have usually been limited to examining one component of the decision making process. Rahm and Huffman (1984), Young and Shortle (1984), and Korsching et al., (1983) were concerned with those factors that affect adoption. They used a dichotomous variable to represent adoption (e.g., 1=adopt, 0=non-adopter). Ervin and Ervin (1982) were also concerned with the adoption stage of the process but instead of a dichotomous variable, adoption was defined by the number of conservation practices used on the farm.

Similar to the approaches used in the analysis of whether or not there had been adoption, soil conservation effort has been measured using a variety of variables. Lee and Stewart (1983, 1985), Heimlich (1985), and Bultena et al., (1983) were concerned with examining the final stage of the

decision making process, that is, the level of conservation effort. These studies used the proportion of cropland not tilled by a moldboard plow as a measure of conservation effort. Ervin and Ervin (1982) define conservation effort as the difference between the estimated farm erosion rate without the use of conservation tillage and the rate obtained given the observed practices. Related to this measure, Saliba and Bromely (1986) used the cover and management ("C") and conservation and support practice ("P") factors from the Universal Soil Loss Equation (USLE) as their measure of effort.

With the exception of Ervin and Ervin (1982) and Norris and Batie (1987), previous models of soil conservation behavior have not been integrated with respect to the stages of the decision making process (i.e., perception of the problem, adoption of practices, and extent of effort). Through the use of a Tobit analysis, Norris and Batie (1987) were able to develop an integrated model of the last two stages for two distinct categories of soil conservation technologies: conservation tillage vs. other conservation practices.¹ They differentiated conservation tillage from other soil conservation investments because conservation tillage may: (a) be undertaken for reasons other than soil conservation such as increasing net returns, reducing on-farm labor requirements, etc. and (b) represent more short term objectives vis-a-vis other soil conservation investments which tend to be long term in nature (also see Lee and Stewart, 1983). In the Norris and Batie model of conservation tillage use, "effort" was measured as the number of seeded acres using a minimum or no-till technology. Their use of acres as the dependant variable did not allow for an analysis of the factors that influence the relative use of conservation

tillage on a farm. Also, given the definition of the dependent variable, it was not surprising that one of the more important explanatory variables in their empirical model was farm size.

The model developed in this study is similar to that presented in Norris and Batie (1987). We build upon their specification by using an alternative definition of the dependent variable in the adoption and use model. The dependent variable in the model developed here is the proportion of all planted acreage not tilled with a moldboard plow. Another extension of the current model is that we explicitly include the first stage of the decision making process (i.e., recognition of an erosion problem).

III. Description of the Data

The data used in the present study were obtained from the 1987 Wisconsin Family Farm Survey (WFFS). The respondents were part of a panel of farm operators that were initially interviewed in the spring of 1983 and who represented a random sample of the 12,240 farm operators in eight counties in southwestern Wisconsin (Salant et al., 1984; Saliba and Bromely, 1986). Extensive information was obtained in both 1983 and 1987 with respect to income sources, assets, debts, off-farm employment, farm business and family characteristics. In the 1987 survey we asked the farm operators to complete a "land use matrix", constructed so that three major pieces of land use information could be obtained: (a) the distribution of total cropland among three slope categories, (b) the distribution of row crops, small grain and hay crops on this cropland, and (c) the type of primary tillage practice used prior to planting.² Table 1 shows that 50.8 percent of farmers used some form of conservation tillage in 1986. We also see that the use of a

chisel plow was the most important type of alternative tillage practice being used on 32.2 percent of planted acreage. Not surprisingly, a greater proportion of the steeper acreage was under conservation tillage.

IV. Description of the Theoretical Model

The first stage of our conservation tillage model examines those factors that influence the producer's level of awareness of an erosion problem and is examined through the use of a single probit equation. The dependent variable in the estimated probit equation, PERCEIVE, was set equal to 1 if the farm operator strongly agreed to the statement that, "soil erosion is an important problem in this area".

The theoretical model of conservation tillage adoption which encompasses the second stage of our model is based on the two limit Tobit model discussed in Maddala (1983) and originally presented by Rossett and Nelson (1975). The two-limit Tobit estimator was used for the adoption model because the dependent variables is a proportion which must be in the range of 0,1 and because of the multi-stage decision making process (i.e., first deciding whether or not to adopt soil conserving technologies and then determining the extent to use these technologies, given the decision to adopt).

We can represent the adoption component of the model as:

$$(1) \quad Y_i^L = \beta'X_i + \mu_i \quad (i=1, \dots, N)$$

where Y_i^L is an unobserved latent variable representing the use of conservation tillage, β is a $(k \times 1)$ vector of unknown parameters, X_i is a $(k \times 1)$ vector of independent variables, μ_i is residual that is assumed to

be independently and normally distributed with mean zero and variance, δ^2 , and N is the number of observations.

If we denote Y_i as the observed dependent variable, e.g., the proportion of cropland acreage devoted to conservation tillage, then:

$$(2) \quad Y_i = \begin{cases} 0 & \text{if } Y_i^L \leq 0 \\ Y_i^L & \text{if } 0 < Y_i^L < 1 \\ 1 & \text{if } Y_i^L \geq 1 \end{cases} \quad i = 1, \dots, N$$

The likelihood function for this model is given by:

$$(3) \quad L(\beta, \delta, Y_i, X_i) = \prod_{Y_i=0} F(-B'X_i/\delta) \prod_{Y_i=Y_i^L} (1/\delta) f([Y_i - B'X_i]/\delta) \prod_{Y_i=1} (1 - F([1 - B'X_i]/\delta))$$

where $F(\cdot)$ and $f(\cdot)$ are the cumulative normal distribution and normal density functions, respectively. Given the limits of Y_i^L , we can define two standardized variables (omitting the subscripts) as:

$$(4) \quad Z_1 = -\beta'X/\delta, \quad Z_2 = (1 - \beta'X)/\delta$$

Extending the results of Tobin (1958) and Maddala (1983), the unconditional expected value of the dependant variable, $E(Y)$, can be represented as:

$$(5) \quad E(Y) = \Pr(Y=0)0 + \Pr(0 < Y^* < 1)E(Y|0 < Y < 1) + \Pr(Y=1)1 \\ = \beta'X[F(Z_2) - F(Z_1)] + \delta[f(Z_1) - f(Z_2)] + [1 - F(Z_2)]$$

The expected value of Y conditional upon being between the limits is:

$$(6) \quad E(Y^*) = E(Y|0 < Y < 1) = \beta'X + \delta([f(Z_1) - f(Z_2)]/[F(Z_2) - F(Z_1)])$$

(see, e.g., Amemiya, 1973). The variable Y^* represents the proportion of acreage cultivated using conservation tillage, given that the operator uses these practices. Combining (5) and (6) we see that:

$$(7) \quad E(Y) = [F(Z_2) - F(Z_1)]E(Y^*) + [1 - F(Z_2)]$$

where $F(Z_2) - F(Z_1)$ is the probability of adopting the soil conserving practices.

From the above, the estimated coefficients, β , do not represent the marginal effects of a unit change in the independent variables on $E(Y)$ or $E(Y^*)$. McDonald and Moffit (1980) suggest a useful decomposition of these marginal effects under the single limit Tobit which can be extended to the two-limit situation. To see this, the three marginal effects can be represented as:

$$(8) \quad \partial E(Y^*)/\partial X_j = \beta_j [1 + (Z_1 f(Z_1) - Z_2 f(Z_2)) / (F(Z_2) - F(Z_1)) \\ - (f(Z_1) - f(Z_2))^2 / (F(Z_2) - F(Z_1))^2],$$

$$(9) \quad \partial [F(Z_2) - F(Z_1)] / \partial X_j = -\beta_j / \delta f(Z_2) + \beta_j / \delta f(Z_1) \\ = \beta_j / \delta [f(Z_1) - f(Z_2)], \text{ and}$$

$$(10) \quad \partial E(Y) / \partial X_j = [F(Z_2) - F(Z_1)] \partial E(Y^*) / \partial X_j + E(Y^*) \partial [F(Z_2) - F(Z_1)] / \partial X_j \\ + \partial (1 - F(Z_2)) / \partial X_j \\ = [F(Z_2) - F(Z_1)] \partial E(Y^*) / \partial X_j + \beta_j / \delta [E(Y^*) (f(Z_1) - \\ f(Z_2)) + f(Z_2)] \\ = [F(Z_2) - F(Z_1)] \beta_j$$

From equation (10) and similar to the single limit Tobit, we can decompose the total effect of a change in an independent variable on the unconditional expected value of the proportion of acres under conservation tillage into three parts: (a) the change in conservation tillage use by those operators who have adopted these practices weighted by the probability of being an operator who has adopted, (b) the change in the probability of being an operator who uses conservation tillage weighted by the expected value of usage given that the operator has adopted and (c) the probability of being at the upper and lower limits.

The primary objective of this study is to examine the effect of various factors on the use of conservation tillage. Given the above theoretical

model we have explicitly incorporated the Ervin and Ervin structure of soil conservation adoption into an integrated model. The first stage of the process is the recognition by the farm operator of a soil erosion problem. From the empirical model of this stage we obtain the predicted probability of perceiving a soil conservation problem which is then used as an explanatory variable in the adoption component of our model (e.g. equations (1)-(7)). By using a Tobit estimator for this latter component, we obtain information with respect to the effect of selected variables on both the probability of adoption and the conditional intensity of conservation tillage use.

V. Explanatory Variables Used in the Analysis

A variety of independent variables are hypothesized to affect the process of adopting soil conservation technologies. The variables used in the equation to explain the perception of a soil erosion problem are similar to those presented in Ervin and Ervin (1982), which included both operator and farm characteristics. Following the approach outlined in Belknap and Saupe (1988), we assume that the adoption and use of soil conservation tillage practices are dependant on three general types of variables: farm, financial and operator characteristics.

5.1 Variables Used in the Soil Erosion Recognition (Probit) Equation

The first component of our empirical model is used to determine those factors that affect the recognition of a soil erosion problem. Over 54 percent of the farm operators indicated a recognition of a soil erosion problem by "strongly agreeing" that soil erosion was an important problem in

their area. The estimated value of the dependent variable in this component is then used as an explanatory variable in the adoption and use equation.

Farm Characteristics

Two farm characteristics are used in the recognition equation. First, the number of acres of cropland (CROP ACRES) which includes all land on which crops are grown and hay was cut as well as any diverted or set-aside acreage. This variable is hypothesized to have a positive impact on the perception of an erosion problem. The greater level of management skills that are expected with larger size operations should enable the farm operator to assimilate information with respect to the impacts of erosion on the soil's long term productivity.

It is hypothesized that the more cropland on the home farm that is susceptible to soil erosion, the more the farmer will recognize the potential for regional erosion related problems. In the present study we did not obtain information about soil type but we did obtain some data about slope and crop mix. The variable STEEPER SOILS, calculated as the proportion of total cropland having a slope greater than seven percent, was hypothesized to have positive effect on the recognition of a soil erosion problem. There is a potential for greater soil loss for those lands that are steeply sloped and this potential loss is an incentive for the farm operator to incur the costs of obtaining information concerning the impacts of excessive soil erosion.

Operator Characteristics

Variables representing several operator characteristics are used in the recognition equation including the number of years of formal education (EDUCATION) and the number of years of experience as a farm operator

(EXPERIENCE). Both are expected to positively affect the recognition of an erosion problem given that, as noted by Ervin and Ervin (1982), higher values should imply an improved ability to obtain and understand information about the productivity and soil conserving effects of alternative tillage practices.³

The third operator characteristic included in the perception model was a dummy variable which was set equal to 1 if the operator had participated in a formal farm related training program in any school or any special private or government agricultural education program over the previous four years. A positive relationship is expected between this variable, FARM TRAINING, and the perception of an erosion problem.

A dummy variable was also included which was set equal to 1 if the farm operator indicated some contact with Soil Conservation Service personnel. We hypothesize a positive relationship between this variable, SCS CONTACT, and the recognition of an erosion problem due to an increased availability of soil conservation information and access to trained personnel.

The last variable include in the perception component of the model was a dummy variable set equal to 1 if the farm operator had the objective of being a full-time farmer for at least the next five years. An operator who plans to be a full-time farmer is expected to be more concerned with maintaining the productivity of the soil when compared to an operator who intends to leave farming in the near future. That is, the retiring farm operator will have a relatively high discount rate on returns obtained by maintaining soil fertility. Thus, the farm operator who plans to stay in production would be more willing to incur the costs of obtaining information with respect to the productivity impacts of soil erosion and whether soil

erosion is a problem on his farm. We therefore hypothesize a positive relationship between this variable, FULLTIME PLANS, and recognition.

5.2 Variables Used in the Conservation Tillage Adoption Equations

The second component of the empirical model is used to explain the process of adopting of soil conserving tillage practices as well as the degree to which this technology has been incorporated into the farm's operations. The statistical model used here incorporates exogenous variables as well as the predicted value of the variable PERCEIVE (i.e., EST.PERCEP) as explanatory variables.

Farm Characteristics

We expect a positive relationship between the number of acres planted to all crops (PLANTED ACRES), and the use of conservation tillage for several reasons. First, given the additional equipment needed when adopting conservation technologies, economies of size can be expected given the ability to spread the fixed costs of this additional equipment over a larger number of acres (Belknap and Saupe, 1988). Secondly, Rahm and Huffman (1984) note that a farm operator has an incentive to adopt this technology if the expected per acre returns are positive. For a given per acre net return, the farm-wide expected returns from adoption are proportional to farm size, which implies a positive relationship between farm size and adoption. Finally, larger size operations may be expected to have greater levels and increased quality of management, and such high management levels are asserted to be required to use reduced tillage techniques, e.g., to optimize the limited amount of cultivation and the increased use of pesticides.

Farm type may be an important determinant of the use of soil conserving technologies. In the present study, the variable DAIRY FARM was set equal to 1 if at least 50 percent of the farm gross receipts was obtained from the sale of dairy or dairy related products. In the sample used in the present study, over 70 percent of the farms were classified as being dairy farms. Ervin and Ervin (1982) assert that cash grain farms tend to have shorter planning periods which imply high discount rates which, in turn, result in less use of conservation tillage. This would imply a positive relationship between the variable DAIRY FARM and adoption. Alternatively, a negative relationship may be expected due to less erosive nature of crops grown by dairy farms (e.g. pasture and forages) which may reduce the expected long run returns from adoption (Saliba and Bromely, 1986).

Those farm operators whose farms have the most potential for experiencing the negative impacts of soil erosion are more likely not only to recognize the existence of an erosion problem but also to undertake soil conservation activities. Soil type, slope, and land use will affect the degree of soil erosion experienced on an a farm. As noted earlier, we did not have information with respect to the type of soil but we did have limited information with respect to slope and rotation. In the planted acreage equation, the variable PROP.LEVEL which represents the proportion of level cropland (with less than 3% slope) was used as an explanatory variable. A negative relationship between this variable and the dependent variable PROP.MINACRES (i.e., proportion of planted acres with conservation tillage) is expected due to the perception that there is little erosion damage on these level soils. The greater the proportion of cropland that is level, the lower the expected returns from adopting these tillage practices.

Information with respect to crop mix is incorporated in the Tobit equation via the use of the variables PROP.ROW and PROP.GRAIN. The variable PROP.ROW is the proportion of planted acreage devoted to row crops and PROP.GRAIN the proportion of planted acreage devoted to small grains and first year seeding of hayland. The erosive nature of row crops when compared to closely seeded crops implies that a farm operator with an intensive row crop rotation will generate a larger stream of benefits from adopting soil conserving technologies compared to an operator with a rotation in small grains or forage crops. We thus expect a positive coefficient on the variable PROP.ROW. Using a similar argument, we expect a negative coefficient associated with the variable PROP.GRAIN.

For the eight counties included in this analysis, the 30-year annual average precipitation level ranged from 30.5 to 33.4 inches. Four of the counties had less than 31 inches of precipitation. A dummy variable, DRY, was set equal to 1 for these lower precipitation counties and was included in the analysis in order to examine the differential adoption rates in those counties with relatively low precipitation levels. Because reduced tillage systems decrease evaporation and increase infiltration due to greater amounts of surface crop residue, adoption of conservation tillage is expected to be greater for those farms receiving lower precipitation levels (Rahm and Huffman, 1984). In an earlier study of this same region, Belknap and Saupe (1988) found a negative relationship between precipitation level and the probability of adoption. Consistent with their results, we hypothesize a positive relationship between the variable DRY and the probability of adoption.

The effect of temperature on the use of conservation tillage is not as clear cut as the effect of precipitation. Rahm and Huffman (1984) assert that because conservation tillage requires less fieldwork during the pre-plant and post-harvest periods, the probability of adoption should be negatively related to the length of the growing season. In addition, because of the effect of surface residue on lowering soil temperature, Belknap and Saupe hypothesized and found a positive relationship between average temperature and the use of conservation tillage.⁴ In the present study, the 30-year average number of heating degree days is used as a proxy for length of growing season. For the eight counties in the study region, the range was from 7016 to 8238 heating degree days. Two counties had 30 year averages of more than 8000 heating degree days. The dummy variable COLD was set equal to 1 for these two counties.

Financial Characteristics

Two financial variables are included in this stage of the analysis. The variable DEBT RATIO is a dichotomous variable set equal to 1 if the debt-asset ratio was greater than .5. A negative relationship between debt levels and the use of conservation tillage is expected. In contrast to the Norris and Batie (1987) study, the absolute level of debt was not used as an explanatory variable in that it was felt that it is the relative debt level that is a determinant of the operator's ability to undertake new investments associated with adopting these conservation practices. In addition, farm businesses with high debt-asset ratios tend to have higher discount rates implying a shorter planning period and a preference for current vs future incomes (Belknap and Saupe, 1988; Ervin and Ervin, 1982).

The second financial variable included in this study was the level of income available to the farm household (HOUSEHOLD INCOME). This total household income was composed of net farm income, off-farm wage income, non-farm self-employment income, investment income, and other passive income and transfers. Higher levels of household income implies a greater ability to purchase additional tillage equipment and materials due to fewer financial constraints. Secondly, with higher tax rates, higher income farm operators receive a larger tax incentive for a given amount of deductible conservation practice expenditures when compared to lower income farm households, thus providing additional incentives for the adoption of these technologies (Ervin and Ervin, 1982; Pampel and van Es, 1977).

Farm Operator Characteristics

A high level of operator education (EDUCATION) should improve the management capabilities of the farm operator. Such management skills are usually required to incorporate conservation tillage practices into the farm operation. With higher levels of operator education, the easier it should be for the operator to obtain and understand information with respect to its applicability to their farming environment and to determine the potential impacts on long run profits.

Older farm operators tend to have shorter planning horizons, implying a high discount rate, which reduces the present value of the future returns from adopting conservation tillage. This shorter planning horizon and the inability to fully capitalize the expected yield changes into land prices implies a negative relationship between operator age (AGE) and adoption (Norris and Batie, 1987; Bultena and Hoiberg, 1983).

In their analysis of conservation tillage, Norris and Batie (1987) used a dichotomous variable to measure the importance of off-farm employment in determining the level of use. In the model presented here, we use the proportion of the operators total work time (total farm and off-farm work hours) that occurs off-farm (PROP.OFF FARM) as a measure of the degree of commitment to the off-farm labor market. In contrast to the assertion of Norris and Batie (1987), we feel that the effect of off-farm work on conservation tillage adoption is unclear. In one sense, with a low level of commitment to agriculture in terms of farming as a source of income or demanding significant amounts of operator time, one would expect less of a concern for maintaining soil productivity (Ervin and Ervin, 1982; Norris and Batie, 1987). Alternatively, a major reason for adopting conservation tillage, in addition to its effect on soil loss, is the lower labor requirements at critical planting periods when compared to traditional cultivation methods. This characteristic could be important for the producer that is attempting to maintain the farm operation while working off-farm.

The variable AGE*OFF-FARM is the product of the variables AGE and PROP.OFF FARM. Due to the uncertain nature of the impacts of the variable PROP.OFF FARM, the impacts of this variable on adoption and use is also unclear. A positive coefficient would tend to support the hypothesis that the use of these reduced tillage systems is a means of reducing farm work time.

The effect of intergenerational considerations on land use are incorporated into the present model via the use of the variable FAMILY TRANSFER which has the value of 1 if the operator intends to transfer the

farm to other family members. Such farm operators have an incentive to maintain the productivity of the soil for these future generations and therefore are more likely to use the conservation tillage technologies (Norris and Batie, 1987).

The perception of the need for undertaking soil conservation strategies is hypothesized to have a positive impact on the use of soil conservation tillage (Taylor and Miller, 1978). The inclusion of variable EST.PERCEP as an explanatory variable in the Tobit equation provides a direct linkage between the recognition of a need for erosion control and the use of conservation tillage.

Appendix A presents the means of the variables used in the probit and tobit regressions. The results of T-tests for differences in the means are also presented.

VI. The Impact of Farm and Operator Characteristics on Adoption and Use of Soil Conserving Tillage Practices

Table 2 presents the results of the probit equation used to explain the probability of recognizing the existence of an erosion problem. The estimated coefficients are of the expected sign with the exception of the coefficients associated with cropland acres. The positive coefficient on the variable CROP ACRES SQ. indicates that the negative relationship is reduced for larger farms.

In addition to the estimated coefficients, the marginal impacts of changes in the independent variables on the probability of recognition are presented. These marginal impacts show that for a 1 percentage point increase in the proportion of acreage classified as being steep (e.g., an increase from 7% to 8%), the probability of recognizing the presence of a

soil erosion problem increases by .42 percentage points. This implies an elasticity of .18 when evaluated at the mean values of the independent variables. One year of additional education was found to result in an increased probability of perception by 3.9 percentage points implying an elasticity of .84. The equation provides a significant amount of explanatory power given a Chi-Square value of 31.9 and a correct classification of 65 percent of the sample.

From the probit results in Table 2, the predicted value of the dependent variable (EST.PERCEP) was determined for each observation, and was used as an explanatory variable in the Tobit equation whose coefficients are presented in Table 3. The sign of the estimated coefficients in this Tobit equation are as hypothesized with the exception of the EDUCATION variable. From the estimated coefficients in Table 3 and using equations (8)-(10), the elasticity of changes in the independent variables on adoption and use are also presented: (a) for those producers who currently do not use minimum tillage, ξ_F , (b) for those who currently use conservation tillage, ξ_{Y*} , and (c) in the total use of conservation tillage, ξ_Y . We can interpret these elasticities as follows: From Table 3, for a 1 percent increase in planted acreage, the proportion of planted acreage under conservation tillage would increase by .369 percent. The probability of current non-users adopting conservation tillage would increase by .168 percent and there would be a .078 percent increase in the proportion of planted acreage using conservation tillage by current users.

VII. Policy Implications for Soil Conservation

A number of economic and farm related variables were found to be associated with the awareness of operators that soil erosion was an important problem in their area and with their use of conservation tillage. With respect to the recognition that soil erosion is an important problem, the results of probit equation indicate, not surprisingly, that farm operators with steeply sloped cropland are more likely to be aware of a soil erosion problem in their area. In addition, the results also indicate that the past use of the Soil Conservation Service by producers was useful as a source of information with respect to the recognition of the impacts of soil erosion.

With respect to the adoption and use of conservation tillage in general, one of the more significant variables was the age of the operator with ξ_Y^* and ξ_Y values of $-.630$ and -1.047 , respectively (Table 3). This negative relationship is in contrast to the positive relationship between perception and experience observed in the probit equation. This contrast shows that less experienced and therefore younger farmers are more likely to adopt alternative tillage practices but it is the older more experienced farm operators that are more likely to recognize that an erosion problem exists. These results imply that efforts to increase adoption and use of soil conservation tillage practices may want to be targeted to the younger less experienced operators because they are less likely to recognize the existence of an erosion problem but given the recognition of a problem they are more likely to adopt these alternative tillage practices.

A similar result was obtained with respect to farm size as measured by crop cropland and planted acres. The results from the recognition equation

suggests that it is the small farm operator that is more likely to recognize the existence of a soil erosion problem. In contrast, given the recognition of the problem, it is the larger operations that are more likely to adopt the soil conserving technologies. Given limited program budgets, information may want to be targeted to these larger operations with the objective of increasing their perception of an erosion problem. If such information programs are successful, these large farms would tend to use conservation tillage to a greater degree than smaller operations.

Producer recognition of the need for soil conservation was found to be an important factor in the adoption of conservation tillage as shown by an ξ_y value of 1.20. This has important implications for program managers in terms of the effect of information on adoption. These results suggest that voluntary adoption of soil conserving technologies may be effective if there are reliable information gathering and disseminating systems that increase the impacts of soil erosion.

Off-farm employment is becoming an increasingly important means of supplementing low levels of farm income. This is an important trend for policy makers concerned with soil erosion given the negative relationship between the variable PROP.OFF-FARM and adoption. In the sample of farm operators encompassed by this study, 30 percent work off-farm with an average of 31 percent of their total work time devoted to an off-farm job. In Table 3 we see that the elasticity values associated with the variable PROP.OFF-FARM are relatively small. Recalculating these elasticity values for those farm operators who work off-farm, the ξ_y values decrease to -.376. These negative ξ_y values imply those farm operators who work off-farm currently do not view conservation tillage as a means of reducing farm work

time commitments. These results also support the hypothesis that farm operators who have less of a commitment to the farm as a source of income may have less of a concern for maintaining soil productivity implying less of a likelihood of undertaking soil conservation activities. Thus soil conservation education programs may need to be established with the target population of "part-time" farmers and with the objective of providing information as to the time savings that may be obtained by the adoption of these tillage practices as well as the economic impacts of adoption.

Examining the impacts of the variables in the present study with those contained in Norris and Batie (1987) allow us to compare the differing effects of changes in the independent variables on the adoption and use of conservation tillage under two different economic and geographic environments. The elasticities obtained under the present study are relatively low compared to those obtained by Norris and Batie. This result may be due to the relatively long history of the soil conservation movement in southwestern Wisconsin. Given that for the Virginia study only 17% of surveyed operators used some form of conservation tillage compared to over 50% in the present study this result is not surprising.

The major response to changes in the values of the explanatory variables for the two county region in Virginia studied by Norris and Batie (1987), as shown by the relative sizes of ξ_F and ξ_{Y^*} was by the adoption of conservation tillage by previous non-users. A similar result was obtained under the current study. One explanation for the results obtained under the present study may be the degree to which users of conservation tillage have integrated this type of technology into their farming operation. Table 4 shows the distribution of acreage by the degree to which alternative tillage

practices are used. For all operators surveyed, a third of the farms have over 60 percent of their planted acreage cultivated using conservation tillage. Calculating similar percentages for just those operators who use conservation tillage, more than two-thirds of the farms have at least 60 percent of their planted acreage under conservation tillage. In addition, 41 percent of the adopters do not use a moldboard plow at all. These relatively high levels of adoption by current users suggest that they may have applied this technology to the extent that soil slope and profitability allow. This implies that the majority of future change in the use of this technology must occur from new adopters. At least for Southwestern Wisconsin, policy makers concerned with soil conservation must recognize the importance of the role to be played by new adopters in attaining their policy objectives.

Table 1. Distribution of Acreage by Conservation Tillage Practice,
Southwestern Wisconsin, 1986

Tillage Practice	All Planted Acreage				Row Crop Acreage			
	All	Nearly Level	Moderate Slope	Steep Slope	All	Nearly Level	Moderate Slope	Steep Slope
Percent of Farms Using Conservation Tillage	.508	.429	.472	.509	.465	.379	.445	.566
Conservation Tillage	Proportion of Planted Acres With							
	.524	.468	.554	.595	.551	.504	.590	.658
Chisel Plow	.322	.254	.358	.425	.327	.261	.384	.461
Shallow Sweep	.145	.151	.143	.135	.152	.165	.142	.122
Ridge-till or No-till	.057	.063	.053	.035	.072	.078	.064	.075

Source: 1987 Wisconsin Family Farm Survey

Note: "Conservation" tillage" is any method of primary tillage excluding the moldboard plow. The first row reports the percent of farms that have each type of land and who use conservation tillage.

Table 2. Estimated Probit Coefficients for the Recognition of a Soil Erosion Problem

Independent Variable	Expected Sign	Units	Mean	Estimated Coefficient	Standard Error	Marginal Impacts ^d	Elasticity ^e
INTERCEPT				-1.6779 ^a	.5652		
<u>Farm Characteristics</u>							
CROP ACRES	+	acres	181.1	-.0020 ^b	.0009	.0006	-.2053
CROP ACRES SQ.	-	acres		.1237E-05 ^c	.6664E-06		
STEEPER SOILS	+	proportion	.2348	1.0486 ^a	.3176	.4167	.1797
<u>Operator Characteristics</u>							
EDUCATION	+	years	11.61	.0993 ^b	.0371	.0395	.8418
EXPERIENCE	+	years	23.86	.0168 ^b	.0075	.0067	.2928
FARM TRAINING	+	(0,1)	.2722	.1217	.1870	.0484	.0242
SCS CONTACT	+	(0,1)	.5077	.2660 ^c	.1588	.1057	.0986
FULLTIME PLANS	+	(0,1)	.5719	.2086	.1634	.0829	.0871

Dependant Variable: PERCEIVE

Log-Likelihood: -209.44

Chi-Squared(D.F.): 31.9(8)

Predicted Correct:^f

Entire Sample: 65.1 percent

PERCEIVE = 0: 57.0 percent

PERCEIVE = 1: 71.9 percent

Note: The superscript "a" represents significance at the .01 level, "b" represents significance at the .05 level, and "c" represents significance at the .10 level.

^dThe marginal impacts are calculated via the following:

$$\partial(\text{Prob})/\partial X_i = [(1/2\pi)e^{(-X\beta^2/2)}] \beta_i.$$

^eThe elasticities were calculated at the mean values of the independent variables.

^fIn terms of classifying observations, if the predicted value of the variable PERCEIVE was greater than or equal to .5, the operator was classified as recognizing that an erosion problem exists in the area.

Table 3: Estimated Tobit Coefficients for the Planted Acreage Equation

Independent Variables	Expected Sign	Units	Mean	Estimated Coefficient	Standard Error	Elasticities		
						ξ_F	ξ_{Y*}	ξ_Y
INTERCEPT				.4967	.7515			
<u>Farm Characteristics</u>								
PLANTED ACRES	+	acres	101.1	.0042 ^a	.0013	.168	.078	.369
PLANTED ACRES SQ	-	acres		-.3149E-05 ^a	.1211E-05			
DAIRY FARM	?	0,1	.7125	-.3531 ^b	.1776	-.190	-.043	-.260
PROP.LEVEL	-	proportion	.4003	-.2112 ^a	.2426	-.066	-.015	-.087
PROP.ROW	+	proportion	.3159	1.2699 ^a	.4835	.267	.077	.414
PROP.GRAIN	-	proportion	.2108	-.1313	.3941	-.023	-.004	-.029
DRY	+	0,1	.4862	.3547 ^b	.1520	.124	.031	.178
COLD	?	0,1	.4710	.3718 ^b	.1633	.110	.035	.181
<u>Financial Characteristics</u>								
DEBT RATIO	-	0,1	.1865	-.3879 ^c	.2071	-.053	-.013	-.075
HOUSEHOLD INCOME	+	\$	30880	.4840E-05 ^b	.2579E-05	.102	.029	.154
<u>Operator Characteristics</u>								
EDUCATION	+	years	11.6	-.0735 ^c	.0409	-.651	-.147	-.882
AGE	-	years	51.1	-.0295 ^a	.0085	-.630	-.194	-1.047
PROP.OFF-FARM	?	proportion	.0933	-6.2288 ^a	1.8540	-.071	-.012	-.093
AGE*OFF-FARM	?		4.89	.1031 ^a	.0325	(-.263)	(-.042)	(-.376)
FAMILY TRANSFER	+	0,1	.1284	.3440 ^c	.2032	.033	.008	.046
EST.PERCEP	+	proportion	.5445	2.1326 ^a	.6215	.867	.204	1.199
Sample Size		327						

Dependant Variable: PROP. MINACRES

Log-Likelihood: -291.61

Chi-Squared (D.F.): 97.95(16)

Note: The superscript "a" represents significance at the .01 level, "b" at the .05 level, and "c" at the .10 level. The elasticities in parenthesis refer to elasticity values for those farm operators who work off farm. The columns of elasticity values were estimated from equations (9), (8), and (10), respectively. Elasticity values were calculated at mean values of the independent variables.

Table 4: Distribution of Farms by Proportion of Acreage Under Conservation Tillage

Proportion of Acres %	Proportion of Farms	
	All Farms %	Adopters %
0	49.2	---
1 - 19	3.7	7.2
20 - 39	3.4	6.6
40 - 59	9.2	18.1
60 - 79	7.0	13.9
80 - 99	6.7	13.3
100	20.8	41.0

Source: 1987 Wisconsin Family Farm Survey

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Footnotes

1. "Other Conservation Practices" included terraces, sod waterways, strip-cropping, critical area planting, pasture or hayland establishment and/or management, cover crops, and tree planting and are measured by annual investment, maintenance, and opportunity costs associated with their investment (Norris and Batie, 1987 p.80).
2. The three cropland slope categories used to classify land were: nearly level (0-2% slope), moderate (3-7% slope) and steep (8% or more slope). For the row crops, five primary tillage practices were identified: moldboard plow, chisel plow 8-12 inches deep, shallow sweeps or disk 2-3 inches deep, ridge till, and no-till. For small grains or the new seeding of alfalfa or clover the above technologies were allowed except for ridge-till planting. No information was obtained with respect to crop residue management. For a discussion of the role of residue management in soil conservation refer to Heimlich (1985) and Lee and Stewart (1985). Throughout this paper the term conservation tillage refers to the use of any primary tillage implement that is not a moldboard plow.
3. An age variable was originally included in the analysis, but because of the multi-collinearity between age and experience, it was dropped from the Probit equation.
4. One reason for the differences in these results may be the variables used to measure the effect of temperature. Saupe and Belknap (1988) used heating degree days while Rahm and Huffman (1984) used the average number of growing degree days between spring and fall with less than a 50% frost probability.

Appendix A

Means of Variables Used in the Recognition and Tobit Regressions

Table A1: Means of Independent Variables Used in Recognition Regression

Variable	Units	Total Sample		PERCEPTION = 1		PERCEPTION = 0	
		Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
CROP ACRES	acres	181.1	176.2	173.9	176.4	189.7	176.2
STEEPER SOILS	prop.	.2348	.2430	.2823 ^a	.2570	.1779	.2121
EDUCATION	years	11.6	2.5	11.9 ^b	2.5	11.3	2.4
EXPERIANCE	years	23.9	12.1	24.4	12.5	23.2	11.5
FARM TRAINING	(0,1)	.2722	.4458	.3089 ^c	.4633	.2281	.4210
SCS CONTACT	(0,1)	.5077	.5007	.5618 ^b	.4975	.4429	.4984
FULLTIME PLANS	(0,1)	.5719	.4956	.5730	.4960	.5704	.4966

Note: The variable PERCEPTION was set equal to 1 if the farm operator indicated that soil erosion was a significant problem in his/her area. Refer to the text for the definition of the variables used here. T-Tests were conducted for differences in the means between the two subpopulations. The superscript "a" indicates significant differences at the .01 level, "b" at the .05 level and "c" at the .1 level, significantly.

Table A2: Means of the Independent Variables Used in the Tobit Analysis

Variable	Units	Total Sample		Adopters		Non-Adopters	
		Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
PLANTED ACRES	acres	101.1	140.0	140.3 ^a	173.13	60.6	76.2
DAIRY FARM	(0,1)	.7125	.4533	.7349	.4427	.6894	.4641
PROP.LEVEL	proportion	.4003	.3163	.4010	.3071	.3990	.3264
PROP.ROW	proportion	.3159	.1857	.3602 ^a	.1801	.2701	.1806
PROP.GRAIN	proportion	.2108	.1855	.1994	.1776	.2225	.1939
DRY	(0,1)	.4862	.5006	.5241	.5009	.4472	.4987
COLD	(0,1)	.4710	.4999	.5602 ^a	.4978	.3788	.4866
DEBT RATIO	proportion	.1865	.3901	.1988	.4003	.1739	.3803
HOUSEHOLD INCOME	\$	30880	28489	34575 ^b	32714	27069	22831
EDUCATION	years	11.6	2.5	11.9 ^c	2.3	11.4	2.7
AGE	years	51.1	12.3	49.1 ^a	11.2	53.1	13.0
PROP.OFF-FARM	proportion	.0933	.2165	.0591 ^a	.1757	.1286	.2473
FAMILY TRANSFER	(0,1)	.1284	.3351	.1325	.3400	.1242	.3308
EST.PERCEP	proportion	.5445	.1513	.5559	.1559	.5310	.1456

Note: Refer to the text for the definition of the variables used here. T-Tests were conducted for differences in the means between the two subpopulations. The superscript "a" indicates significant differences at the .01 level, "b" at the .05 level and "c" at the .1 level, significantly.