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The Role of Environmental Education in Predicting Adoption of Wind Erosion Control Practices

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Logit and ordered probit analyses were used to identify factors associated with reduced tillage adoption, continuous spring cropping, and the number of changes made in response to wind erosion. Contrary to previous results for water erosion control, simple perception of a wind erosion problem or membership in a particular socioeconomic category did not significantly explain adoption of wind erosion control practices, but participating in a targeted educational program did. This educational program: (*a*) highlighted the threats of wind erosion to human health and to soil productivity, and (*b*) described specific potentially profitable farming practices for solving the wind erosion problem.

Key words: environmental education, logit, probit, soil conservation, technology adoption, wind erosion

Introduction

Much of the technology adoption literature has emphasized resource characteristics and human capital factors as explanatory variables. The latter include education, experience, age, and structural-economic variables such as size of farm and tenancy status (Feder, Just, and Zilberman; Harper et al.; Nielsen, Miranowski, and Morehart; Ervin and Ervin; McNamara, Wetzstein, and Douce). The theoretical rationale for human capital variables in adoption of new, but profitable, technologies is clear. Higher levels of education are viewed as contributing to better allocative decisions which encourage adoption of profitable practices. Higher age decreases the time horizon for payoff from new technologies, which discourages adoption. Larger farm size multiplies the payoff from a new technology, thus encouraging adoption. Renting compared to ownership of land discourages adoption because renting eliminates asset appreciation gains from technology adoption and shortens the payoff horizon.

For the adoption of soil conservation technologies at the farm level, Ervin and Ervin hypothesized a richer stagewise process of adoption. At the first stage, the farmer recognizes the existence of the soil erosion problem, at the second the farmer decides whether or not to adopt a conservation practice, and finally the level of adoption in terms of

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intensity or area is determined. Ervin and Ervin modeled stage 1 as a farmer's perception of "the degree of erosion problem on his land ... [measured as] ... severe (3), moderate (2), slight (1), and none (0)" (p. 282). Gould, Saupe, and Klemme modeled stage 1 with a binary variable to signify agreement or disagreement with the statement: "the operator strongly agrees that erosion is an important problem in the area" (p. 170). Shiferaw and Holden used a four-level scale "of the parcel's exposure to soil erosion ranging from no risk of soil erosion (0) to high exposure to soil erosion (3)" (p. 238).

The slightly different soil erosion perception variables in these three studies were found to be highly statistically significant in predicting adoption of the number of conservation practices used on Missouri farms (Ervin and Ervin), use of conservation tillage on Wisconsin farms (Gould, Saupe, and Klemme), and retention of conservation structures on Ethiopian farms (Shiferaw and Holden). These and other conservation adoption studies (e.g., Lee and Stewart; Rahm and Huffman; Norris and Batie) have focused on practices for controlling water erosion of soil.

While the profit-maximization model using human capital and resource characteristics variables has dominated the economics technology adoption literature, proponents of the new socioeconomics approach have advocated using more "fundamental" psychological and sociological causal variables such as "favoring an outdoor lifestyle" or "having a studious temperament" (Lynne and Casey; Casey and Lynne). Although the socioeconomic approach may present challenges in variable measurement, it likely will provide new insights on relevant policy incentives. However, given the data available to this study and the desire to compare our wind erosion control adoption results to previous water erosion control results, we pursue the traditional profit-maximization approach.

Water erosion, compared to wind erosion, often leaves more visually dramatic impacts on the landscape, such as gullies. These and other differences could cause variations in adoption behavior for water and wind erosion control practices. However, few if any studies appear to have been directed toward predicting the adoption of wind erosion control practices by individual farmers. Nevertheless, several studies have measured the substantial on-site and off-site benefits of controlling wind erosion (Huszar and Piper; Piper and Huszar; Davis and Condra; Piper and Lee; van Kooten and Thiessen), compared the benefits and costs of specific wind erosion control practices (Hu, Ready, and Pagoulatos; Lee, Bryant, and Lacewell), and evaluated the economic and political feasibility of different policies to mitigate wind erosion damage (Bunn 1998, 1999).

In view of the promising results from incorporating perception of the soil erosion problem in past soil conservation technology adoption research, it would be useful to directly compare the influence of a targeted conservation education program to the influence of simple perception of an erosion threat. This comparison could provide useful policy guidance on undertaking targeted educational programs.

Our threefold objective in this analysis is to statistically evaluate: (*a*) a variable measuring knowledge of a wind erosion educational program, (*b*) a variable measuring perception of the farm-level erosion threat, and (*c*) several socioeconomic variables in predicting the adoption of wind erosion control practices by a sample of eastern Washington State farmers. Our study incorporates variables reflecting stages 1 and 2 of Ervin and Ervin's adoption framework.

The study was made possible by a unique educational program in the study region initiated three years prior to the survey which provided the data for this analysis. The campaign emphasized (*a*) the negative effects of wind erosion on human health and soil productivity, and (*b*) specific potentially profitable farming practices to reduce wind erosion (Scott et al.). The educational campaign was named "PM-10," which refers to dust particles less than 10 microns in diameter. These particles have been shown to be related to respiratory illnesses, and national clean air laws specify maximum levels for PM-10 to ensure public health and safety (Schwartz). The PM-10 Project, spearheaded by the U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service and Cooperative Extension, utilized leaflets, newspaper articles, broadcast media, and farmer meetings to deliver its messages on wind erosion dangers and solutions.

Wind Erosion Problem

The two key practices for controlling wind erosion in eastern Washington are reduced tillage (no-till and min-till) and conversion from summer fallow-winter wheat to continuous spring grains. Wind erosion is worse on bare, dry, and unfrozen summer fallow. No-till and min-till leave more protective crop residue in the field. Continuous spring cropping eliminates summer fallow and ensures crop or stubble cover both in summer and winter. Both practices effectively control erosion, but they are relatively new in the study region.

A recent study based on dust levels in a nearby city caused by wind erosion in the Columbia Plateau predicted that improved summer fallow with min-till or no-till reduced PM-10 dust by 31% to 54% when compared to conventional tillage summer fallow. Continuous spring cropping reduced predicted PM-10 dust by 95% compared to the conventional summer fallow-winter wheat rotation (Lee). Recent evidence indicates that properly conducted conservation tillage and continuous spring cropping can be more profitable in this study region than traditional practices (Camara).

Model Framework

Because variables related to the adoption of soil conservation practices are qualitative, logit and probit models are used (Hanushek and Jackson). The two binary practice adoption variables (*NO/MIN TILL* and *CONT SP CROP*) serve as the dependent variables in the two logit models (table 1). The binomial logit model is defined as:

(1)
$$P(y = 1) = \frac{\exp(\mathbf{x}\beta)}{1 + \exp(\mathbf{x}\beta)},$$
$$P(y = 0) = \frac{1}{1 + \exp(\mathbf{x}\beta)},$$

where the dependent variable, y, takes the value of 1 if a particular practice is adopted, and 0 otherwise; $\mathbf{x}$ is the row vector of independent variables, which may include a constant; and β is the corresponding parameter vector. The larger $\mathbf{x}\beta$, the higher the probability of adoption of the practice.

When a dependent variable is multinomial of degree m (that is, it takes m different ordinal values), the following ordered probit model is appropriate:

Table 1. Description of Variables in Wind Erosion Control Practices Adoption Models

Variable Name	Description
Dependent Variables:	
NO/MIN TILL	1 if using no-till or min-till, 0 otherwise
CONT SP CROP	1 if using continuous spring cropping, 0 otherwise
CHANGES MADE	Changes in practices due to wind erosion: 0 if no changes, 1 if very few changes, 2 if some changes, 3 if a lot of changes
Independent Variables:	
KNOWLEDGE PM-10	Knowledge of PM-10: 0 if no knowledge, 1 if slightly knowledgeable, 2 if somewhat knowledgeable, 3 if very knowledgeable
PROBLEMS W/EROS	Problems with wind erosion in last 10 years: 0 if no problems, 1 if 1 or 2 problems, 2 if 3 to 5 problems, 3 if more than 5 problems
FARM SIZE	Acres
LEASE%	Percent of farmland leased from nonfamily
OFF-FARM INCOME	Source of household income: 1 if mostly from farm, 2 if roughly same from farm and off-farm, 3 if mostly off-farm
EDUC	Highest level of education completed: 0 if no post-secondary, 1 if some college or technical school, 2 if college graduate
AGE	Years

(2)
$$P(y = m - 1) = \Phi(\mathbf{x}\boldsymbol{\beta}),$$
$$P(y = m - 1 - i) = \Phi\left(\mathbf{x}\boldsymbol{\beta} + \sum_{j=1}^{i} c_j\right) - \Phi\left(\mathbf{x}\boldsymbol{\beta} + \sum_{j=0}^{i-1} c_j\right),$$
$$P(y = 0) = 1 - \Phi\left(\mathbf{x}\boldsymbol{\beta} + \sum_{j=0}^{m-2} c_j\right), \qquad i = 1, \ldots, m - 2,$$

where $c_0 = 0$; c_1 through c_{m-2} are positive parameters in the ordered probit model to be estimated; and $\Phi(\cdot)$ is the cumulative density function of a standard normal distribution.

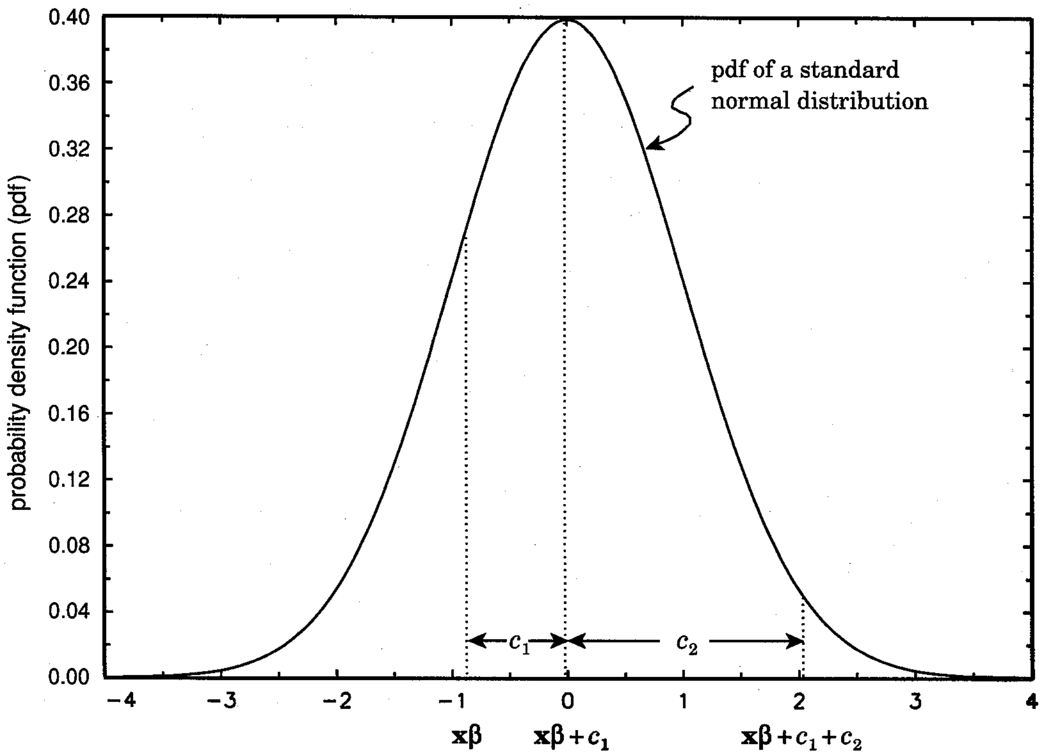

Figure 1. Illustration of an ordered probit model of degree 4

In this study, a multinomial variable of degree 4, indicating the amount of changes made in farming practices because of wind erosion, serves as the dependent variable in the ordered probit model (table 1).

Figure 1 illustrates the probabilities of y taking alternative values under the ordered probit model of degree $m = 4$. The probability of $y = 3$ is the area under the standard normal probability density function (pdf) curve up to the first vertical dotted line at $\mathbf{x}\beta$. The probability of $y = 2$ ($y = 1$) is the area under the pdf curve between the first (second) and second (third) vertical dotted lines, and the probability of $y = 0$ is the area under the pdf curve to the right of the third vertical dotted line.

While the first line has the horizontal reference of $\mathbf{x}\beta$, the $c_1, c_2, \ldots, c_{m-2}$ values are the widths between each pair of adjacent vertical lines from left to right. If $\mathbf{x}\beta$ is relatively large for a particular farmer, then the first vertical line will lay further to the right, indicating the farmer has a higher probability of making a lot of changes due to wind erosion. As the $\mathbf{x}\beta$ line moves to the right, all the other vertical lines are pushed to the right while maintaining the relative distance between each adjacent pair of lines constant. This will reduce the probability of the rightmost category ($y = 0$). The effects on all the middle categories are ambiguous, depending where they are located on the standard normal pdf curve. Usually, those located to the right of the symmetric distribution have lower probabilities, while those to the left have higher probabilities.

Both logit and ordered probit models share the same seven independent variables, as identified in table 1. The first independent variable is the survey respondent's ranking of her or his knowledge of the PM-10 program in the study region (*KNOWLEDGE PM-10*). Higher levels of knowledge of PM-10 issues were hypothesized to contribute positively to adoption of wind erosion control practices. It is unlikely that area farmers would have been familiar with the technical term "PM-10," except through the previously described wind erosion educational campaign named PM-10. *KNOWLEDGE PM-10* is expected to be positively correlated with adoption of wind erosion control practices.

The second independent variable (table 1), *PROBLEMS W/EROS*, elicits the grower's frequency of problems with wind erosion in the past 10 years. This variable is intended to be an objective measure of the farmer's perception of the wind erosion threat on the farm as opposed to the grower's knowledge of the broader set of wind erosion dangers and solutions conveyed in the PM-10 educational campaign. *PROBLEMS W/EROS* is hypothesized to be positively correlated with use of conservation practices based on prior results in the literature.

FARM SIZE, *LEASE%*, and *OFF-FARM INCOME* are three common economic variables utilized in technology adoption studies. *FARM SIZE* is hypothesized to be positively correlated with wind erosion control practice adoption based on theory (Feder, Just, and Zilberman) and on the results of earlier reduced tillage adoption studies (Rahm and Huffman; Lee and Stewart; and Norris and Batie). *LEASE%* was assigned no a priori sign. Lee and Stewart argue that conservation tillage, unlike traditional structural conservation investments, may not be impeded by tenancy. Conservation tillage often reduces operating costs, and a tenant can frequently institute the practice without landlord approval. These arguments are empirically supported by Lee and Stewart, who reported a statistically significant positive relationship between reduced tillage adoption and the proportion of leased land. Our second specific practice adoption variable, conversion from summer fallow-winter wheat to annual spring cropping, can also often be adopted by tenants without landlord approval.

We assign no a priori sign to *OFF-FARM INCOME* due to possibly offsetting influences. Increased management requirements of new conservation technologies might preclude part-time farmers from adopting them. On the other hand, conservation tillage (albeit not spring cropping) could save time, especially if custom no-till drilling were employed. As previously argued, *EDUC* was hypothesized to be positively associated, and *AGE* negatively associated, with adoption of wind erosion control practices. Natural resource characteristics—such as soil types, topographic features, and climatic factors—are also important in the adoption of conservation practices (Rahm and Huffman; Gould, Saupe, and Klemme). These resource characteristics were not included in the survey providing the data for this study because of the relatively uniform agro-climatic features of the study region (Scott et al.). The region has been dominated by the summer fallow-winter wheat cropping system for the century it has been farmed.

Data and Estimation

Data were developed from a telephone survey of a random sample of farmers residing in Adams, Benton, Douglas, Franklin, and Grant counties of east-central Washington State (Scott et al.). These counties are located in an arid region of Washington susceptible to wind erosion. The survey was conducted during mid-1997. The complete questionnaires

Table 2. Means and Standard Deviations for Dependent and Independent Variables, 266 Eastern Washington State Farms, 1997

Variable	Units	Mean	Std. Dev.
Dependent Variables:			
NO/MIN TILL	(0, 1)	0.203	0.403
CONT SP CROP	(0, 1)	0.259	0.439
CHANGES MADE	(0, 1, 2, 3)	1.579	0.909
Independent Variables:			
KNOWLEDGE PM-10	(0, 1, 2, 3)	1.305	0.968
PROBLEMS W/EROS	(0, 1, 2, 3)	1.139	0.886
FARM SIZE	acres	3,263	2,593
LEASE%	%	23.8	30.5
OFF-FARM INCOME	(1, 2, 3)	1,327	0.707
EDUC	(0, 1, 2)	1.045	0.761
AGE	years	53	13

used for this analysis included 266 farmers who represented 59% of the original sampling frame, a relatively high response and completion rate for a telephone survey.

Table 2 reports the means and standard deviations for the dependent and independent variables utilized in this study. About one-fifth and one-fourth of the responding farmers were using reduced tillage and annual spring cropping, respectively. Twenty-nine (11%) of the farmers were using both practices, but a separate category was not specified for this group. Based on the scale in table 1, the respondents had an average index of changes in their practices due to wind erosion of 1.579 (table 2).

On average, the responding farmers were somewhat more than "slightly knowledgeable" about PM-10, with a mean score of 1.305 (table 2). The mean of 1.139 for *PROBLEMS W/EROS* indicates that responding farmers had observed slightly more than "1 or 2" wind erosion problems on their farm in the past 10 years (based on the scale shown in table 1). Farm size varied from 60 to 18,000 acres, with an average of 3,263 acres. The percentage of farmland leased from nonfamily individuals averaged 23.8%. In this rural region, most family income came from farm sources. Farmers in the sample averaged 53 years of age, and on average the farmers had some college or technical school education. The standard deviations in table 2 indicate considerable dispersion in both the dependent and independent variables.

Although not included in table format here, absolute pairwise correlations among the independent variables were low—below 0.15, with three moderate exceptions. *AGE* and *EDUC* exhibited the highest absolute pairwise correlation of −0.372. This conforms with the conventional pattern that younger adults have more education. The 0.245 correlation between *FARM SIZE* and *LEASE%* suggests that larger farms have grown by leasing land. Operators of larger farms probably have less time available to earn off-farm income, which may explain the negative correlation of −0.258 between *FARM SIZE* and *OFF-FARM INCOME*. Interestingly, the correlation coefficient between *KNOWLEDGE PM-10* and *PROBLEMS W/EROS* was only 0.069. Possibly, this low correlation is rooted in the less dramatic visual effects of on-site wind erosion compared to on-site water erosion. Indeed, some program participants may not have perceived the wind erosion problem prior to being exposed to the PM-10 educational program. This possible difficulty in perceiving on-site wind erosion damage is also reinforced by estimates that on-site damage from wind erosion may be only one-tenth or less of off-site damage (Piper). Consequently, farmers may be slow to perceive personal "problems with wind erosion." Involvement in an educational program like *KNOWLEDGE PM-10* may have raised both their private and social consciousness.[1]

Maximum-likelihood logit estimation was used for each of the two binary dependent variable equations. Maximum-likelihood ordered probit estimation was used for the multinomial dependent variable equation. Previous studies of soil conservation technology adoption have used logit (Lee and Stewart) and probit (Rahm and Huffman) estimators for binary dependent variables. Both have appeal on theoretical and empirical grounds (Capps and Kramer). The ordered probit was appropriate due to the qualitative progression in magnitude of the multinomial dependent variable (*CHANGES MADE*). We estimated both logit and probit models for the two binomial adoption variables, with very similar results. We chose to report only the logit results based on the convenient mathematical and theoretical properties of the logit model advanced by Hanushek and Jackson, and by Pindyck and Rubinfeld.

In previous studies, perception variables representing the first stage of the adoption process have been included both directly with other explanatory variables and recursively as predicted values from a separate equation (Ervin and Ervin; Gould, Saupe, and Klemme). Reporting on both approaches, Shiferaw and Holden obtained a better fit to the data and a more intuitive explanatory comparison with the direct approach. Following Shiferaw and Holden's results, we include these variables directly in the adoption equation with other variables. The limited number of variables in our data set to estimate separate perception and knowledge equations also favored the direct approach.

Results

Table 3 reports the estimated coefficients, coefficient significance levels, and equation performance measures for the three adoption equations. Fewer statistically significant variables are observed in this wind erosion control practice adoption study than in previous water erosion control adoption studies. However, the *KNOWLEDGE PM-10* variable was significant at the 90% or higher confidence level for all three equations. Knowledge of the PM-10 educational campaign was significantly related to the adoption of no/min-till, the adoption of continuous spring cropping, and the number of changes made in farming practices due to wind erosion. In contrast, perception of the number of erosion problems experienced in the last 10 years (*PROBLEMS W/EROS*) was significantly related only to the *CHANGES MADE* adoption variable. Given the unspecified nature of the practices adopted in the *CHANGES MADE* variable, this response has a less clear interpretation than those for adoption of specific conservation practices. It is possible that different farmers have different perceptions of what constitutes changes made in response to wind erosion.

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[1] We are grateful to an anonymous reviewer for suggesting this potential explanation of the low correlation between *PROBLEMS W/EROS* and *KNOWLEDGE PM-10*.

Table 3. Maximum-Likelihood Coefficient Estimates and Equation Performance Measures for Factors Associated with Adoption of Wind Erosion Control Practices

	NO/MIN TILL (Logit)		*CONT SP CROP* (Logit)		*CHANGES MADE* (Ordered Probit)	
Factor	Coeffic.	Signif.	Coeffic.	Signif.	Coeffic.	Signif.
KNOWLEDGE PM-10	0.292	0.084**	0.261	0.087**	0.187	0.008***
PROBLEMS W/EROS	-0.090	0.628	-0.099	0.560	0.213	0.009***
FARM SIZE	0.000166	0.0044***	0.000084	0.130*	0.000041	0.197
LEASE%	-0.001	0.849	-0.002	0.675	0.002	0.431
OFF-FARM INCOME	0.155	0.501	0.186	0.363	-0.104	0.312
EDUC	0.332	0.149*	0.188	0.362	0.040	0.685
AGE	0.010	0.496	-0.013	0.324	-0.005	0.434
Constant	-3.322	0.002***	-1.328	0.145*	0.800	0.061**
c_1					0.919	0.000***
c_2					2.245	0.000***
Equation Significance (χ^2)		0.036***		0.230		0.00034***
Log Likelihood		-126.7		-147.6		-325.5
% Correct Predictions		80%		74%		47%

Note: Single, double, and triple asterisks (*) denote significance at the .15, .10, and .05 levels, respectively.

The logit results in table 3 for adoption of specific practices contrast with those reported by Ervin and Ervin; Shiferaw and Holden; and Gould, Saupe, and Klemme. In those three water erosion control practice adoption studies, simple perception of an erosion problem was always significantly related to practice adoption, but the coefficients of the *PROBLEMS W/EROS* variable never approached significance in our two logit models. Possibly, simple perception of the more dramatic gullies and sedimentation associated with water erosion might be sufficient to motivate adoption, whereas the more subtle effects of wind erosion on soil productivity and the landscape might not be sufficient to do so. Our results suggest the subtle nature of wind erosion might make adoption less likely unless the problem is accompanied by an educational program which: (*a*) highlights the threats of wind erosion to human health and to soil productivity, and (*b*) outlines specific potentially profitable practices for solving the problem.

FARM SIZE is the only significant socioeconomic variable in the two logit models, at the 0.4% level for no/min-till and at 13% for continuous spring cropping. These results indicate larger farms are more likely to adopt these effective, but potentially risky, wind erosion control practices in this eastern Washington study region. The financial risk of buying expensive no-till drills might be more easily managed by larger farms. Switching to spring cropping concentrates farming operations into a narrow spring window which usually necessitates more machinery and possibly hired labor. Larger farms might be better equipped for this major conversion in farming systems. If no/minimum tillage and continuous spring cropping are profitable, larger farmers will multiply these gains over more acres. Gould, Saupe, and Klemme; Lee and Stewart; Norris and Batie; and Shiferaw and Holden also found a positive relationship between farm size and conservation practice adoption.

Education has shown mixed directions of influence in past conservation adoption studies (Gould, Saupe, and Klemme; Norris and Batie; Shiferaw and Holden). *EDUC* was positive and significant at barely the 15% level in only the *NO/MIN TILL* equation in this study (table 3). Unlike the three studies cited above, our results for adoption of wind erosion control practices consistently failed to show a significant negative relationship with *AGE* and *LEASE%*. *OFF-FARM INCOME* also showed no significant relationship to adoption in all three equations.

The reasons for the lack of a significant relationship between theoretically appealing socioeconomic variables and wind erosion control practices are not entirely known, but some hypotheses can be suggested. The theoretical arguments underlying socioeconomic variables in technology adoption are generally premised on the assumption of profitable new technologies. Wind erosion control is a new concept in the study area, and the evidence on the profitability of no/min-till and annual spring cropping (especially the latter) is limited to case studies of a few experienced farmers (Camara). Risk is an important omitted variable in the adoption model. Farmers probably view any change from the traditional wheat-fallow cropping system as risky in this 9- to 14-inch annual rainfall region. While risk factors are likely to be important, risk perceptions and risk preferences were not available in our survey data. Only Ervin and Ervin included a risk factor among the adoption studies reviewed, and they found risk aversion to be negatively related (at the 10% level) to the number of conservation practices adopted by Missouri farmers.

The overall significance of the three adoption equations is mixed (table 3). Based on the χ^2 statistic, the *NO/MIN TILL* and *CHANGES MADE* equations are significant at the 3.6% and 0.034% levels, respectively, while the *CONT SP CROP* equation is significant at only the 23% level. Nevertheless, the two logit equations predict 74% to 80% of adoption choices correctly. The ordered probit equation predicts 47% correctly, but this is not particularly low considering the four different levels of the dependent variable.

The two width parameters, c_1 and c_2, in the ordered probit model are positive and significant, findings which are appropriate in this setting. As shown in figure 1, $c_2 > c_1$ (i.e., the distance between the last two vertical lines is larger than that between the first two lines); however, this doesn't necessarily mean the probability of $y = 1$ is higher than $y = 2$. This probability depends on where the lines are located, which in turn is determined by $\mathbf{x}\boldsymbol{\beta}$.

Conclusions

The results of this study of factors related to the adoption of wind erosion control practices in an arid farming region indicate that simple perception of a wind erosion problem, or membership in a particular socioeconomic category, was not sufficient to motivate adoption of wind erosion control practices. This analysis provides strong statistical support for a targeted educational program which: (*a*) highlights the threats of wind erosion to human health and to soil productivity, and (*b*) describes specific potentially profitable farming practices for solving the wind erosion problem.

An advantage of the two-pronged educational campaign conducted in this arid farming region is that it appeals both to farmers' sense of social responsibility and to their profit motive. Policy makers often may be in the position of promoting new environmentally sound technologies. These results suggest that a broad-based educational campaign may be a useful first step in fostering such technologies.

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