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Structural Conservation Practices in US Wheat Production: A Cost-Function Technology Adoption Approach[1]

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ABSTRACT *Based on 2004 CEAP-ARMS Phase II data, higher-sales farms not participating in a conservation programme adopted farmland conservation structures much more intensively on wheat fields than did any other farm-size type among conservation programme participants or non-participants. Survey results suggest that wheat farms not participating in a conservation programme more frequently adopted infield conservation structures, while conservation programme participants more often installed field perimeter conservation structures. Wheat producers, particularly those not participating in a conservation programme, recognize productivity and profitability benefits of infield structures as sufficient to promote their adoption without programme incentives. However, for field perimeter structures, programme incentives may be needed to encourage their adoption because benefits are more commonly off-site. To supplement univariate comparisons between conservation programme participants and non-participants, we used a cost-function based acreage allocation model to examine adoption of structural conservation practices, including such practices as strip cropping, terraces, grassed waterways, field borders, and stream-side herbaceous buffers. To accurately assess the potential environmental impacts of conservation programmes, it is important to account for the variability in on-site field, farm, and environmental conditions influencing producer adoption decisions. Econometric models suggest that not accounting for factors such as field, farm, operator, and environmental attributes will likely under- or overestimate adoption of conservation structures with respect to input and commodity prices, regardless of programme participation status.*

Introduction

Since the 2002 Farm Security and Rural Investment (FSRI) Act, the US Department of Agriculture's (USDA) conservation programmes have placed more emphasis on conservation of 'working farmland'—farmland used primarily for crop production and grazing. While land retirement programmes still account for more than half of all USDA conservation expenditures, funding for working-land conservation programmes has increased

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steadily since 2000 and these programmes should account for nearly half of the conservation budget over the next few years (Claassen, 2008). Working-land programmes assist farmers in implementing and maintaining land management practices, including conservation tillage, crop rotation schedules, encouraging use of cover crops, improving nutrient management practices, use of precision agriculture, irrigation water management, and installation of infield and field perimeter structures such as strip cropping, terraces, and stream-side herbaceous buffers.

The Environmental Quality Incentives Program (EQIP) and Conservation Security (now Stewardship) Program (CSP) are USDA’s primary working-land programmes. EQIP provides financial assistance to encourage the integration of conservation structures and practices into farm production systems, and the CSP uses stewardship payments to reward ongoing conservation efforts by producers recognized as exemplary land stewards (Aillery, 2006).

However, the environmental performance of US agriculture is influenced by many factors other than conservation programme characteristics in addition to farmer adoption of conservation practices (Claassen, 2004). Notwithstanding profit maximizing objectives, farmers may adopt conservation practices for a variety of reasons, including differences in operator or farm business characteristics, lifestyle choices, farm succession, off-farm job opportunities, even site-specific environmental characteristics (Smith & Weinberg, 2004; Lambert *et al.*, 2006). In addition, best land management practices and their environmental benefits often make good business sense absent programme incentives (Hopkins & Johansson, 2004). The challenge to accurately assess the impact of conservation programmes on agriculture’s environmental performance therefore involves isolating the influence of programme incentives from other factors that may encourage adoption of conservation technologies and best management practices.

To respond to this challenge and enhance USDA’s ability to assess the economic and environmental benefits of conservation programmes, USDA integrated two producer-based surveys. In 2004, USDA’s Natural Resource Conservation Service (NRCS), the Economic Research Service (ERS), and the National Agricultural Statistics Service (NASS) instituted a pilot national survey integration programme; the Conservation Effects Assessment Project—Agricultural Resource Management Survey (CEAP-ARMS). CEAP, developed and managed by NRCS, involved the collection of producer field-level production practice, programme participation, and associated National Resources Inventory (NRI) point-based environmental data.[2] Initiated in 2003, the CEAP project was designed to quantify the impact of conservation practices and evaluate the environmental effectiveness of conservation programmes at the watershed scale and from an aggregate national perspective. ARMS, developed and managed by ERS, involves the collection of field production practice and cost-of-production data, along with farm-level resource, economic, and household characteristic information. By integrating CEAP and ARMS data, CEAP-ARMS allows USDA to more effectively isolate the impacts of conservation programmes, that is, differentiating the environmental benefits generated by producers participating in conservation programmes from those using similar conservation technologies, but not participating in conservation programmes.

Producer decisions to allocate field acres to infield or field perimeter conservation structures may be correlated with the acreage allocation decision for crop production on the field. This study defines infield conservation structures as terraces, grass waterways, vegetative buffers, contour buffers, vegetative filter strips, and grade stabilization structures. Field perimeter conservation structures include hedgerow plantings, stream-side forest and herbaceous buffers, windbreaks and vegetative wind barriers, field borders, and critical habitat planting areas. The 2004 CEAP-ARMS data for wheat suggest that, while conservation programme participants likely make a positive contribution to reducing agriculture-related environmental problems, the largest contribution to environmental benefits may come from higher-sales farms producing wheat, but not participating in conservation programmes. In this analysis, we separate conservation programme participants from non-participants because it may be important to assess the number and types of farms who adopted conservation practices without financial assistance, and the reasons why. In addition, producer-based economic frameworks based solely on profit maximization may only partially explain the adoption behaviour of programme participants and non-participants. However, use of on-site socio-environmental data from an integrated data base may yield a more accurate assessment of adoption behaviour, conservation programme participation, and programme effectiveness by accounting for land heterogeneity (such as soil erosion, drainage, proximity to a river or lake, and wildlife habitats) not typically measured in other farm production/environmental surveys (Lambert *et al.*, 2007a).

This paper evaluates producer field-level technology adoption decisions for US wheat production of a variety of infield and field perimeter conservation structural practices, differentiating adoption behaviour between conservation programme participants and non-participants using two approaches. First, conservation programme participants and non-participants are compared in a univariate analysis. Characteristic differences between these groups by farm-size class are identified using pairwise t-tests. Second, an empirical model is developed to determine the extent to which input costs and crop prices are correlated with the decision to dedicate portions of a field to infield or perimeter conservation structures, or only to crops (in this analysis, wheat). Two versions of this model are estimated to highlight the importance of integrating traditional producer production practice and farm economic data with field-level programme participation and on-site environmental information.

The remainder of the paper: (1) describes the use of CEAP-ARMS data; (2) summarizes for 2004 wheat producers' key characteristic differences between conservation programme participants and non-participants by farm-size class; (3) presents a crop-specific, cost function acreage allocation model of producer conservation technology adoption decisions; and (4) discusses empirical model results and concludes with some policy implications.

CEAP-ARMS Data

CEAP, ARMS, and CEAP-ARMS are surveys conducted by USDA's National Agricultural Statistics Service. ARMS, an annual crop-specific survey based on a list-frame sample design (Phase I), collects field-level production practice, input use, and cost-of-production data (Phase II questionnaire), and farm-level resource, economic, and operator/household data (Phase III follow-on questionnaire). CEAP, using an area frame sample design, collects more detailed field-level production practice and programme participation data, along with site-specific environmental data from USDA's NRI.[3]

The 2004 Phase II CEAP-ARMS included a sample of 882 NRI point-based farm fields (for wheat) across 16 states.[4] The response rate was 85%. When integrated with NRI data, the usable Phase II sample was 732 observations, and when the Phase II/NRI data was integrated with the Phase III farm-level economic/farm resource data, the usable sample was 472 observations.[5] This integrated database provides an opportunity to characterize the differences between wheat producers participating or not participating in one or more USDA conservation programmes by an ERS farm typology.

Using CEAP-ARMS Phase II data, programme participants were defined as respondents who identified either conservation financial assistance programmes in their conservation plan for the surveyed field, or that conservation compliance applied to the field (i.e., the field was registered as meeting the requirements for 'Highly Erodible Land Conservation Compliance (HELCC)').[6,7] The definition of farm size classes (used only within the univariate analysis), using Phase III ARMS data, were defined by Hoppe & MacDonald (2001). However, because of the smaller Phase III sample size, the ERS typology was collapsed into three farm-size classes: (1) retired/residential/lifestyle farms; (2) farms with total sales < $100 000 and the operator's primary occupation was farming ('low-sales'); and (3) farms with total sales ≥ $100 000 and the operator's primary occupation was farming ('higher-sales').[8] Paired t-tests were used to compare the characteristic differences across programme participants and non-participants, as well as across the farm types.

Because of the complex survey design of ARMS and CEAP-ARMS, variances used to construct t-tests for the univariate comparisons between conservation programme participants and non-participants, by farm type, were estimated based on standards established by USDA's National Agricultural Statistics Service, using a delete-a-group jackknife variance estimator (Kott, 1997).

US Wheat Production: Characteristic Differences by Programme Participation and Farm-Size

The 2004 CEAP-ARMS indicates that only about a third of the farms growing wheat (accounting for only 30% of planted wheat acres) participated in a conservation programme on their 2004 wheat acres (Figure 1). Wheat farms participating in conservation programmes on wheat acres differed in a number of ways from other wheat farms not participating in conservation programmes on wheat acres, and by farm size class (Table 1).

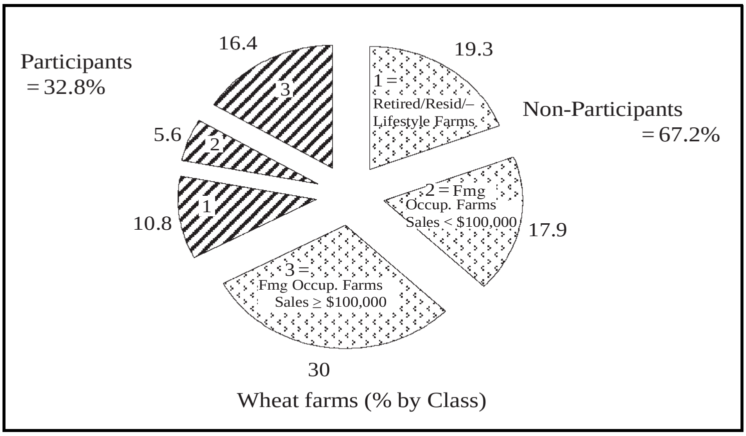

Figure 1. Percent distribution of 2004 CEAP-ARMS respondents for wheat: conservation programme participations vs. non-participants by farm-size class.

Source: 2004 CEAP-ARMS Wheat Survey, Economic Research Service, USDA.

Table 1. Average field/farm characteristics for 2004 wheat producers, by conservation programme participation and by farm-size class

	Non-Participant Farms			Participant Farms		
Field/Farm Characteristics	Retired/-Residential/-Life-style	Farming-Occupation/-Sales < \$100,000	Farming-Occupation/-Sales ≥ \$100,000	Retired/-Residential/-Life-style	Farming-Occupation/-Sales < \$100,000	Farming-Occupation/-Sales ≥ \$100,000
General Field/Farm Values	A	B	C	D	E	F
Pct. of wheat farms (horizontal = 100)	19.3CE[c]	17.9CE	30.0ABDEF	10.8C	5.6ABCF	16.4CE
Farm acres operated (ac.)	797CF	609CF	2,258ABDE	1,124CF	902CF	2,478ABDE
Farm wheat acres harvested (ac.)	119CF	179CF	559ABDE	153CF	202CF	517ABDE
Pct. of wheat acres planted (horizontal = 100)	13.1CDE	16.6CDE	40.2ABDEF	6.2ABCF	5.7ABCF	18.3CDE
Acres owned to acres operated (ratio)	.61E	.75CF	.41BE	.69	.87ACF	.31BE
Farm Financial Values						
Farm total value of production (\$)	58,531CF	47,804CF	474,013ABDE	133,554CF	41,845CF	462,172ABDE
Ave. farm revenue share from wheat (%)	21.0E	31.0	26.0E	14.0	52.0ACF	21.0E
Total farm net worth [equity] (\$)	307,137CDF	686,364C	1,728,406ABDE	839,473AC	494,133C	1,233,541A
Ave. net farm income (\$)	– 7,719C	13,706C	85,049ABE	48,358	2,694C	8,969
Operator Characteristics						
Ave. operator age	55	60CF	52B	54	58	49B
Pct. operators with some college (col. %)	16.3C	20.6	28.4AE	40.0	15.9CF	25.4E
Pct. farms with primary operator working off-farm (col. %)	83.8C	30.6	22.9AF	47.3	45.8	14.1C
Government Payments (\$/farm)						
Direct government payments	3,088CF	3,469CF	24,104ABDE	9,952C	4,719CF	19,059ABE
Counter-cyclical payments	2,828CF	1,932CF	5,544ABF	10,418	2,913F	9,121ABCE
Conservation payments[a]	2,739F	1,914CF	4,922BF	11,970	5,971	12,187ABC
Loan deficiency payments (LDPs, etc.)	3,607CF	1,313CF	13,733ABE	8,165	364CF	9,103ABE

(*Continued*)

Table 1. (*Continued*)

	Non-Participant Farms			Participant Farms		
Field/Farm Characteristics	Retired/-Residential/-Life-style	Farming-Occupation/-Sales < $100,000	Farming-Occupation/-Sales ≥ $100,000	Retired/-Residential/-Life-style	Farming-Occupation/-Sales < $100,000	Farming-Occupation/-Sales ≥ $100,000
Total government payments	4,281CF	5,401CF	34,976ABE	29,709	8,841CF	31,546ABE
Agri-Environmental Values						
Ave. harvested wheat yield (bu./ac.)	48	46	57EF	48	39C	43C
Ave. nitrogen applied (lbs./ac.)	59.7E	46.9CF	73.6BDE	46.1CF	39.6ACF	80.4BDE
USLE soil loss (tons/acre/year)	1.4F	4.7	2.0F	8.1	1.9F	4.1ACE
Pct. wheat farms with gully erosion in wheat fields (col. %)	8.1	17.6	7.8	X[b]	7.5	8.8
Pct. farms with wheat field adjacent to a water body or wetland (col. %)	18.5	46.6	28.4DE	20.7C	22.9C	35.1
Pct. of wheat acres [with wetlands in wheat field] (col. %)	X	14.0	4.4	X	14.2	1.7
Pct. of wheat acres [with HEL acres in wheat field] (col. %)	7.7CF	12.7CF	15.4ABDE	23.9CF	7.9CF	53.6ABDE
Pct. of wheat farms [meeting HELCC for surveyed wheat field] (col. %)	NA[d]	NA	NA	66.8	57.9F	54.5E

Source: 2004 CEAP-ARMS Wheat Survey (integrated Phase II & III data), Economic Research Service, US Department of Agriculture.

Notes: [a] Conservation payments here, for non-participants and participants, include government payments for conservation activities for the entire farm, and not just payments that apply to wheat acres.

[b] X = insufficient observations.

[c] Pairwise statistical significance tests were conducted using two-tailed delete-a-group Jackknife t-statistics at a 90% confidence level or higher. The letters A, B, C, D, E, and F identify the columns with associated pairwise statistical significance.

[d] NA = not applicable.

Farms not participating in conservation programmes on wheat acres (accounting for nearly 70% of planted wheat acres) had larger net farm incomes and greater farm equity than their counterparts participating in conservation programmes. Net farm income for higher-sales farms growing wheat but not participating in a conservation programme was nearly 9.5 times that of higher-sales farms participating in a conservation programme. In addition, CEAP-ARMS data indicates that wheat farms also differ characteristically across programme participation and farm type in operator age, education, use of off-farm work to supplement household income, and in the level of government payments received per farm (Table 1).

More interestingly, a number of agri-environmental characteristics also differed between conservation programme participants and non-participants, and across farm size classes. For example, higher-sales farms not participating in a conservation programme produced the higher wheat yields, but they also applied relatively high rates of nitrogen. The average Universal Soil Loss Equation (USLE) measure of soil loss on wheat fields was greatest for retired/residential/lifestyle farms participating in conservation programmes, but, in 2004, these farms accounted for only 6% of total wheat acres planted. In addition, a larger share of non-participant farms had wheat fields with gully erosion on the field,[9] or the wheat field was adjacent to a water body, intermittent stream, or wetland. Not surprisingly, wheat fields located on Highly Erodible Lands (HEL acres) were more common among the higher-sales farms participating in conservation programmes.[10]

Given these characteristic differences, producers growing wheat have adopted a variety of land-management practices for economic, conservation, and environmental reasons. In 2004, higher-sales farms producing wheat but not participating in conservation programmes (on wheat acres) were the dominant users of all land-management practices included in the survey instrument (Figure 2). In addition, producers also installed a variety of conservation structures (defined earlier) in and around wheat fields to reduce wind and water-based soil erosion, protect surface water sources, and enhance agricultural biodiversity; including creating and enhancing natural habitat pathways across the agricultural landscape (Figure 3). In 2004, field acres devoted to terraces were the dominant structural practice observed on wheat fields. But again, programme non-participants were the dominant users of these structures and their environmental benefits, as evidenced by the fact that these farms accounted for 67% of the total wheat acres.

Overall, the univariate comparisons suggest that non-participants adopted infield conservation structures more frequently, while conservation programme participants appear to give greater emphasis to field perimeter conservation structures. Apparently, many wheat producers recognize the productivity (and therefore profitability) benefits of infield structural practices as sufficient to encourage their adoption without programme incentives. But producers may also recognize that the primary benefits of field perimeter structures are generally off-site, and therefore, these technologies may require some incentive to encourage their adoption. All else equal, producers may be more willing to adopt field perimeter structures when compensated (at least in part) for their opportunity costs (i.e., the net value of lost productive field-crop capacity). This may be of particular importance to larger operations because they generally farm larger fields which are more likely to be adjacent to waterways or other sensitive habitats. Moreover, for the larger non-participant operations (in the 2004 survey), infield conservation structures could have been adopted more frequently because maintaining soil productivity and curbing soil erosion may be relatively more important longer-term planning objectives for these operations.

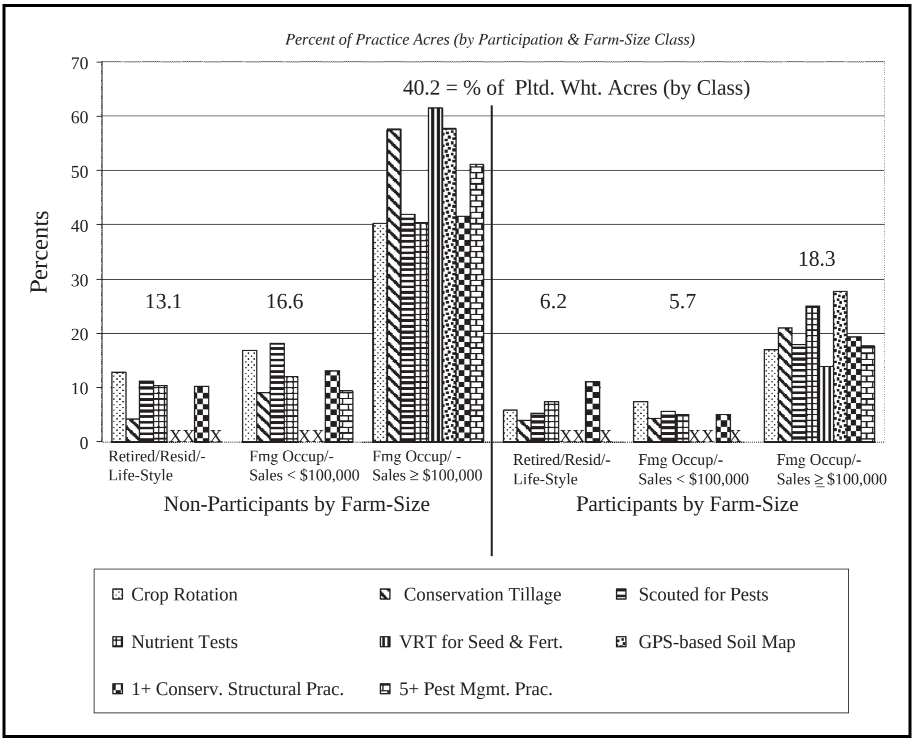

Figure 2. Land-management conservation practices for 2004 wheat.
VRT = Variable Rate Technology; GPS = Global Positioning System.
Source: 2004 CEAP-ARMS Wheat Survey, Economic Research Service, USDA.
Note: X = Insufficient data for this item.

Production Technology Adoption: A Cost Function Acreage Allocation Approach

We supplement the univariate comparison of farms participating and those not participating in conservation programmes with econometric models that focus on field acreage allocation decisions of wheat and conservation structures with respect to relative input costs. Empirical models examining producer acreage allocation decisions to crops and installation of conservation structures are derived from an indirect cost function. The first model (Model 1) correlates adoption of conservation structures as a function of input costs normalized by commodity (wheat) prices, the types of conservation structures available, and when the structure(s) was(were) installed. The second model (Model 2) extends Model 1 by including farm operation and field-level environmental characteristics. Both models differentiate conservation programme participant and non-participant adoption of infield and field perimeter conservation structure technologies. Model 2 demonstrates the importance of integrating on-site environmental data with conventional producer production practice, economic, and programme participation information.

Since the mid-1980s, empirical studies have examined a variety of farm technology adoption decisions in US agriculture, including the adoption of double-cropping of wheat and soybeans (Marra & Carlson, 1987), the adoption of reduced-tillage and genetically-modified

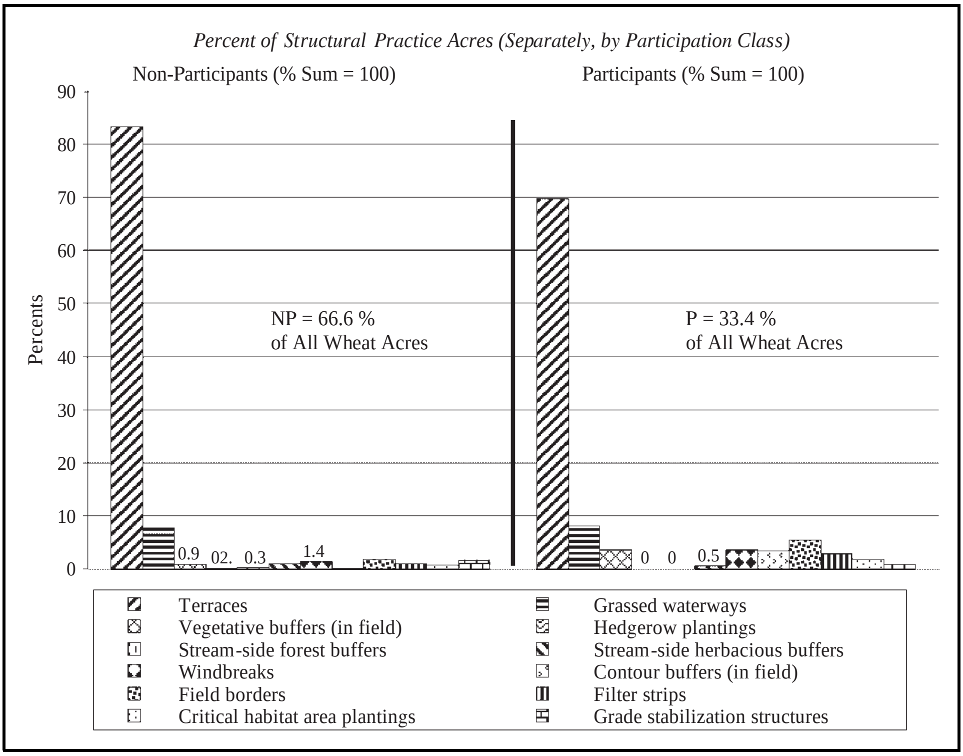

Figure 3. Conservation structural practices for 2004 wheat.
Source: 2004 CEAP-ARMS Wheat Survey, Economic Research Service, USDA.

crop varieties (Rahm & Huffman, 1984; Alexander *et al.*, 2003), adoption of sustainable agricultural practices (D'Souza *et al.*, 1993), and the adoption of water-conserving irrigation technologies (Caswell & Zilberman, 1985; Lichtenberg 1989; Schaible *et al.*, 1991; Schaible & Aillery, 2003; Shrestha & Gopalakrishnan 1993). Depending on available data and the kind of technology adopted, these analyses generally evaluated adoption behaviour as a dichotomous choice using a variety of probabilistic decision frameworks, including logit, probit, limited tobit, and multinomial logit specifications. Two relatively recent studies further advanced these empirical applications (Cooper & Keim, 1996; Lichtenberg, 2004).

Cooper and Keim, using a dichotomous choice approach and data from a USDA survey across four US Geological Survey watershed regions, evaluated: (1) producer willingness to adopt land management practices (not including conservation structural practices) assuming randomly pre-assigned bid values; and (2) practice-based programme acreage responsiveness of producers who indicated that they were not currently using a technology. Lichtenberg, using a dual approach and discrete farm-level adoption data for the state of Maryland, defined latent conservation practice demand relationships from a farm-level land valuation model to estimate practice-specific adoption demand equations separately for seven land management and structural conservation practices.

Both Cooper and Keim, and Lichtenberg made significant contributions towards producing policy-relevant information for conservation programme design and implementation.

However, the Cooper and Keim acreage response relationships (based on stated-preference data), more likely reflect hypothetical behaviour, rather than actual producer behaviour. In addition, their analysis did not account for the conservation behaviour of farms not participating in public conservation programmes. Lichtenberg's dual approach, based on revealed preference data, while a significant improvement, made use of single equation estimation, thereby ignoring the potential bias associated with correlated decision-making. The use of discrete choice data for technology adoption behaviour also limits the model's policy applicability.

To date, most probabilistic models of agricultural technology adoption have been established as direct or indirect variations of the Just and Zilberman (1983) land wealth-based random utility maximization framework. Designed to evaluate producer technology-specific acreage share allocation decisions, this framework assumes dichotomous choice information, fixed landholdings, and full utilization of land resources. In other words, traditional probabilistic models of agricultural technology adoption based on the log of the odds of choosing an advanced technology over a conventional technology have been used *under the assumption that available cropland is fully utilized or cropland is predetermined*.[11] In addition, while general probabilistic technology forecasts may be useful, models estimated using continuous behavioural response data are generally viewed more useful for programme benefit/cost analyses (Cooper & Keim, 1996; Lichtenberg, 2004).

Given the availability of continuous, revealed preference data from the CEAP-ARMS, and given that a probabilistic model is not suitable for the study of crop-specific technology adoption where acres allocated to a crop is not predetermined, this paper uses a dual approach (following Lichtenberg, 2004; Kim *et al.*, 2005) to evaluate producer conservation structural practice decisions on cropland. We develop a generalized, cost-function based acreage allocation model to evaluate crop-specific producer production technology decisions across a variety of infield and field perimeter conservation structure choices that could be installed on a field, which in turn could otherwise be used entirely for crop production (in the present case, wheat). Our dual approach extends previous technology adoption analyses by simultaneously modeling the differential behaviour between conservation programme participants and non-participants.

Extending the dual approach established by Kim *et al.* (2005), the theoretical approach here compares cost functions across alternative conservation structure technologies between conservation programme participants and non-participants. Let $c(y_{i,p})$ and $c(y_{j,p})$ be per acre cost functions for producing output using the i^{th} and j^{th} conservation production technologies by the p^{th} programme participation class (p = 1,2 for conservation programme participants and non-participants, respectively), where $(y_{i,p})$ is per acre yield. Also, $y_{i,p}$ is a function of output price, P_y, and inputs, x, where x is a function of input prices w. Let $y_i / y_j = m$, then $[c(y_{i,p}) / c(y_{j,p})] = m^{\rho_{ij}(p)}$ (see Chambers, 1988, p. 70, equation 2.18), where $\rho_{ij}(p)$ is the cost elasticity of relative output for the i^{th} and j^{th} technologies and the p^{th} programme participation class, such that:

$$\rho_{ij}(p) = d\,ln\left(\frac{c(y_{i,p})}{c(y_{j,p})}\right) \Big/ d\,ln\left(\frac{y_{i,p}}{y_{j,p}}\right) \text{ (where } d \text{ represents differentiation).} \qquad (1)$$

The per acre cost function $c(y_{i,p})$ can then be rewritten as:

$$c(y_{i,p}(x_1, x_2, \ldots, x_n)) = c(y_{j,p}(x_1, x_2, \ldots, x_n))A(y_{j,p}), \tag{2}$$

where $A(Y_{j,p}) = (y_{i,p}/y_{j,p})^{\rho_{ij}(p)}$ is the acreage required for the j^{th} conservation technology to produce $y_{j,p}$ with the same budget constraint (i.e., $c(y_{i,p})$), and x_k is the k^{th} input per acre. When $\rho_{ij}(p) = 1$, the j^{th} farm is characterized as having a constant return to size, and, therefore, a constant return to scale. When $\rho_{ij}(p) > 1$, the j^{th} farm exhibits diseconomies of size, and therefore, a decreasing return to scale. Similarly, when $\rho_{ij}(p) < 1$, the j^{th} farm exhibits economies of size, and therefore, an increasing return to scale. Partial differentiation of equation (2) with respect to the k^{th} input price, $w(k)$, yields:

$$\frac{\partial c(y_{i,p})}{\partial w(k)} = A(y_{j,p})\left(\frac{\partial c(y_{j,p})}{\partial w(k)}\right) + c(y_{j,p})\left(\frac{\partial A(y_{j,p})}{\partial w(k)}\right). \tag{3}$$

Applying Shephard’s lemma results in the following derived demand for the k^{th} input for the i^{th} conservation technology and p^{th} participation class:

$$x_{i,p}(k) = A(y_{j,p})x_{j,p}(k) + c(y_{j,p})\left(\frac{\partial A(y_{j,p})}{\partial w(k)}\right). \tag{4}$$

Multiplying both sides of the equality in equation (4) by $w(k)/A(y_{j,p})$, rearranging terms, and use of $c(y_{i,p}) = c(y_{j,p})A(y_{j,p})$ from equation (2), we obtain an equation for acreage response for the j^{th} conservation technology and p^{th} participation class relative to the k^{th} input cost change as:

$$\left(\frac{\partial A(y_{j,p})}{\partial w(k)}\right)\left(\frac{w(k)}{A(y_{j,p})}\right) = \left[\left(\frac{w(k)x_{i,p}(k)}{c(y_{i,p})}\right) - \left(\frac{w(k)x_{j,p}(k)}{c(y_{j,p})}\right)\right]. \tag{5}$$

Equation (5) reveals that the elasticity of acreage required for the j^{th} conservation technology to produce $y_{j,p}$ equals the difference between the k^{th} input cost shares of products $y_{i,p}$ and $y_{j,p}$.

To derive a functional form of the acreage function for the j^{th} conservation technology and p^{th} participation class, divide both sides of the equality in equation (5) by $w(k)$. After rearranging terms the resulting equation is:

$$d[\ln A(y_{j,p})] = \left[\left(\frac{x_{i,p}(k)}{c(y_{i,p})}\right) - \left(\frac{x_{j,p}(k)}{c(y_{j,p})}\right)\right]dw(k). \tag{6}$$

Integrating both sides of equation (6) with respect to $w(k)$ results in the exponential expression:

$$A(y_{j,p}) = \exp\left[\left(\frac{w(k)x_{i,p}(k)}{c(y_{i,p})}\right) - \left(\frac{w(k)x_{j,p}(k)}{c(y_{j,p})}\right)\right]. \tag{7}$$

Assuming producers minimize cost, and assuming linearly homogeneous production functions, the k^{th} input cost share represents the elasticity of output with respect to the k^{th} input (see Chambers, 1988, p. 241). In addition, since each input is used up to where the value of the marginal product of the k^{th} input equals its unit price, $w(k)$, then equation (7) can be rewritten as follows:

$$A(y_{j,p}) = \exp\left[\left(\frac{x_{i,p}(k)}{y_{i,p}}\right)\left(\frac{w(k)}{Py}\right) - \left(\frac{x_{j,p}(k)}{y_{j,p}}\right)\left(\frac{w(k)}{Py}\right)\right]$$

$$= \exp\left[\beta_i(k)\left(\frac{w(k)}{Py}\right) - \beta_j(k)\left(\frac{w(k)}{Py}\right)\right] = \exp\left[\sum\nolimits_i \tilde{\beta}_i(k)\frac{w(k)}{Py}\right], \tag{8}$$

where $\tilde{\beta}_i(k) = \beta_i(k)$ and $\tilde{\beta}_j(k) = -\beta_j(k)$ and the signs associated with $\tilde{\beta}_i(k)$ and $\tilde{\beta}_j(k)$ are the opposite. These parameter estimates represent the inverse of the k^{th} input productivity of producing output (y) for the i^{th} conservation technology.

An estimable econometric acreage supply function for the j^{th} conservation production technology for the p^{th} participation class, consistent with the theoretical model in equation (8), is:

$$A_{j,p}(y_{j,p}) = exp\left\{\psi_0 + \sum_k \sum_i \tilde{\beta}_i(k) D_i\left(\frac{w(k)}{Py}\right) + \sum_{i=1}^{m-1} \delta_i D_i\right\} + \varepsilon_j, \tag{9}$$

where ψ_0, $\tilde{\beta}$, and δ are parameters, D_i is a dummy variable associated with the i^{th} conservation production technology, ε_j is an iid random disturbance term, and where $\tilde{\beta}_j(k)[w(k)/P_y] = [\partial \ln A_{j,p}(y_{j,p})/\partial \ln w(k)]$ so that $\sum_k \sum_j \tilde{\beta}_j(k)[w(k)/P_y] \neq 0$ also implies that the j^{th} conservation production technology for the p^{th} participation class is non-homothetic (Antle, 1984).

Empirical Estimation

For the cost function approach discussed above, both conservation programme participants and non-participants are assumed to recognize the changes in output and costs associated with shifting field acres from crop production to conservation structural practices (i.e., $A_{j,p}$, alternative field-level conservation technology choices). Therefore, it is likely that decisions to allocate field acres to infield or perimeter conservation structures are correlated with the field acreage allocation decision for wheat production.

Efficiency may be improved if this information is appropriately modeled. Typically, an approach similar to seemingly unrelated regression (SUR) could be used to estimate the contemporaneous correlation between management decisions. But to model the assumptions about decision-making and economic behaviour implied by the cost function approach derived above, the data arrangement is similar to the data structures used in nested or conditional logit regressions. Unlike these regressions, however, the dependent variable in this analysis is continuous. Also, equation (9) suggests a non-linear (exponential) econometric model. To attend to these issues and to exploit the inherent correlation between acreage allocation choices of individual producers, a Generalized Estimating Equations (GEE) approach was applied (Liang & Zeger, 1986).[12]

The GEE procedure is flexible because it can account for the correlation between adoption decisions where the outcomes of these decisions result in countable, continuous units (i.e., acres allocated to wheat, infield, field perimeter, or both infield and field perimeter conservation structures) while maintaining the advantages of discrete conditional choice models. The GEE procedure is also advantageous in that it accommodates certain general non-linear functional forms, including exponential functions. A GEE equation system models the correlation resulting from repeated measures on a given respondent (the ‘subject effect’), or dependencies across clusters of observations (between ‘groups’) using a variety of covariance structures. We assume that the operator is faced with a set of land-management practices (i.e., he or she may choose to allocate field acres to crop production without or with infield or field perimeter conservation structures, or both—the ‘within-subject’ effects). Because of the trade-offs between field crop production technologies (that is, between field crop production without conservation structures and field crop production with acres set aside for alternative conservation structures) the decision to allocate acres to one practice or another may be correlated. For this study, wheat field acreage supply equations (equation 9) are estimated for four production technology decisions, that is, for acres of wheat production for: (1) wheat fields with no conservation structural practices (i.e., acres are only allocated to wheat); (2) wheat fields with only infield conservation structures; (3) wheat fields with only field perimeter conservation structures; and (4) wheat fields with both infield and field perimeter conservation structures. The correlation between the conservation technology choices allocated to crop production was modeled using an unstructured J by J working correlation matrix (where J = wheat only, wheat and infield structures, wheat and field perimeter structures, and wheat and both conservation structures). The acreage supply equations were simultaneously estimated for conservation programme participants and non-participants.[13,14]

Two empirical models were estimated. For Model I, acreage allocation decisions for 2004 wheat fields were modeled as a function of relative per-unit input prices for nitrogen, agricultural wages, and diesel fuel, as well as three technology choice variables and three structural-installation time-period variables.[15] Input prices were normalized using the average wheat price (per bushel) by state.[16] The relative prices are expected to reflect the effect of the primary economic factors affecting a conservation programme participant/non-participant’s perception of field production profitability for the alternative acreage allocation choices for the field.[17] Acreage supply equations were estimated jointly for conservation programme participants and non-participants. Conservation technology class variables (for infield, field perimeter, or both structures) and installation time-period variables (installed in 2004, within the last 10 years, or prior to 1990) were defined as (1, 0) variables, where 1 defined installation or use of that particular technology.

Model II included the same variables as Model I, but with additional covariates to control for the potential influence of farm structure, field crop management, and other site-specific environmental attributes on the allocation of production acres to conservation structures. Farm structure was measured using total cropland acres operated for the farm and by a variable measuring land tenure (the proportion of acres owned to total farm acres operated). Total cropland acres are hypothesized to measure the influence of farm size (including, in part, economies of field size) on operator decisions to install working-land conservation structures. Field management, specifically the use of a crop rotation plan for the field, is hypothesized to capture farm operator concerns with respect to longer-term crop productivity of the field.

Four covariates were included in Model II to measure the influence of site-specific environmental attributes, including the use of surface drainage structures, the occurrence of gully erosion on the field, whether the field was adjacent to a water body, intermittent stream, or wetland, and if the farm operator expressed concern about improving the quality of nearby aquatic or wildlife habitat. Surface drainage and gully erosion are also potential indicators of field-level soil fragility. Covariates identifying proximity of a field to a nearby water source, and producer concerns for fish and wildlife habitat, may indicate that conservation structures were installed to enhance, among other things, off-site environmental benefits.

Models I and II were estimated with the integrated Phase II/NRI 2004 CEAP-ARMS data (732 field/farm observations representing about 1.1 million farms and 53 million wheat acres across the 16 surveyed States). The delete-a-group jackknife procedure was used to make inferences about means of groups analyzed in the paired t-tests (Table 1), and for the GEE regressions. The GENMOD procedure in SAS version 9 was used to estimate the equation system for each model.

Empirical Results

Producers respond to some relative input prices when allocating field acres between wheat production and infield or field perimeter conservation structures, or both (Model 1, Table 2). Results suggest that conservation programme participants and non-participants could have different structural practice adoption patterns in response to relative price changes. For conservation programme participants, relative nitrogen prices were positively correlated with the decision to allocate field acres to both infield and field perimeter conservation structures. For operators not participating in a conservation programme, nitrogen prices were positively correlated with wheat acres planted when infield structures were present, but were not associated with the allocation of field acres to field perimeter structures. For these operators, relative nitrogen prices were also not correlated with wheat field acres planted when no structural practices were present. These results suggest that as the relative price of nitrogen increases, operators not participating in a conservation programme may invest more in infield conservation structures to improve profitability and field productivity. For this same group (i.e., non-participants), an increase in agricultural wages relative to wheat prices was negatively associated with the number of wheat acres planted. On the other hand, for these operators, fuel costs (as measured by diesel prices) were negatively associated with wheat acres planted on fields with infield structures, suggesting that their impact on acre allocation decisions is likely through their influence on field-level cost (or productive capacity).

Table 2. Model I estimated GEE coefficients for wheat field acreage allocation equations by field structural practice (technology), and by conservation programme participation [Model I: $(A_{j,p})$ = f (normalized input prices, technology class & installation variables)]

	Programme Non-Participants		Programme Participants	
Equation/Variable	Estimate	T-tests[b]	Estimate	T-tests
Wheat Field Acres Planted (with):				
No structural practices:[a]				
Constant	5.7112*	4.35	7.4149*	4.35
N price	–3.2293	–0.21	–42.2507***	– 1.73
Ag. Wage	–1.2075*	–3.01	–0.8531	– 1.34
Diesel price	3.7714	0.59	10.3585	0.75
Only infield structures:[a]				
Constant	4.4901	1.34	6.1938*	1.66
N price	47.7303**	1.85	37.5986	1.19
Ag. Wage	0.1248	0.13	–0.5343	–0.53
Diesel price	–17.2925***	–1.57	–8.6014	–0.78
Only field perimeter structures:[a]				
Constant	10.5638	1.34	12.2675	1.48
N price	0.7853	0.02	–24.5268	–0.03
Ag. Wage	1.6317	0.50	–11.6325	–0.11
Diesel price	–37.2729	–1.15	79.9359	0.09
Both structural practices:[a]				
Constant	5.3788	1.16	7.0825	1.41
N price	33.3784	0.59	117.3182**	2.06
Ag. Wage	3.0980	0.99	–2.8054	–0.79
Diesel price	–42.5550	–1.31	–9.2186	–0.29

Installation Dummy Variables:		Estimate	T-tests
Installed in 2004	(Yes = 1)	0.0322	0.22
Installed within last 10 years	(Yes = 1)	0.0191	0.30
Installed prior to 1990	(Yes = 1)	0.2153*	3.56

Log Likelihood Value (L_1) = 107,872,646

# of wheat farms = 732 [1.1 million (weighted)]
Conservation programme participants = 33 %
Conservation programme non-participants = 67 %

Wheat field observations (weighted) with:
No conservation structures = 67.8 %
Only infield structures = 21.1 %
Only field perimeter structures = 6.3 %
Both infield and perimeter structures = 4.8%

Source: 2004 CEAP-ARMS Phase II data, Economic Research Service, USDA.

Notes: Infield conservation structural practices included terraces, grassed waterways, vegetative buffers, contour buffers, filter strips, and grade stabilization structures. Field-perimeter structural practices included hedgerow plantings, stream-side forest buffers, stream-side herbaceous buffers, windbreaks or herbaceous wind barriers, field borders and critical habitat plantings.

[a] State average per unit prices (2004) for nitrogen ($/lb), agricultural wage ($/hr.), and diesel ($/gal.) were normalized using state average 2004 wheat price ($/bu.).

[b] Critical values for the t tests are 1.52 (***), 1.76 (**), and 2.14 (*) for the 15 %, 10 %, and 5 % significance levels, respectively. Standard errors were estimated using the delete-a-group Jackknife approach (Dubman, 2000).

The installation timing of conservation structures installed on the field was correlated with the acreage allocation decisions of wheat producers, but only for older structures. Conservation structures installed before 1990 had, holding other factors constant, a positive and significant relationship with acres allocated to wheat production. Therefore, accounting for installation timing appears to be important with respect to crop and conservation structure acreage allocation decisions. Structures installed at least 14 years before the survey likely had realized or sustained productivity impacts than more recently installed conservation structures.

Model II included additional farm characteristics and environmental variables. In general, what these results suggest, for all producers, is that other factors, such as farm operation and environmental variables, may be important with respect to understanding adoption behaviour of infield and field perimeter conservation structures in addition to input cost and commodity price. Model II largely corroborates the results from Model I, and the univariate comparisons of conservation programme participants with non-participants in that wheat farms not participating in a conservation programme appear to place greater emphasis on the adoption of infield conservation structures (Figures 2 and 3). In general, Model II results (Table 3) were similar to those for Model I, demonstrating some degree of robustness across the different specifications.

The significance of the socio-environmental variables in Model II suggests that a higher farm tenure ratio, larger farm size, as well as field-specific environmental factors (i.e., the occurrence of field gully erosion or the presence of a surface drainage system) positively influence producer field acreage-allocation decisions across conservation technologies. The findings suggest that producers may also consider other factors that complement profit maximizing objectives when installing conservation technologies on farmland that could otherwise be allocated entirely to crop production. Field-specific environmental factors appear to have played a stronger role in these decisions than did farm size. These results are consistent with previous research on programme participation in the Conservation Reserve Program (Lambert *et al.*, 2007b), and on producer adoption of conservation-compatible management practices (Lambert *et al.*, 2007c). In other words, conservation practices promising higher farm profits or improved productivity may not appeal to some producers if they require lifestyle changes that are inconsistent with household goals. For example, if off-farm employment contributes to farm household income more than farm revenue, then minimizing the amount of time the producer spends farming may be more important than maximizing farm profits (e.g., possibly allocating more acres to infield or perimeter structures instead of to crops) (Nehring *et al.*, 2002). Concerns over farm succession (Wilson, 1997; Battershill & Gilg, 1997), the desire to reduce the time and energy involved in farming (Lobley & Potter, 1998), and the need for income stability (Loftus & Kraft, 2003) may also affect conservation practice adoption on land that could otherwise be used entirely for crop production.

Summary and Conclusions

With the 2002 Farm Security and Rural Investment Act, the emphasis of USDA’s conservation programmes shifted towards working-farmland conservation practices. While retirement of fragile lands remains a key component of conservation policy, greater attention to working-land conservation practices highlights the need to understand the potential impacts of USDA’s EQIP and Conservation Security (now Stewardship) Programs on farm household well-being, farm management decisions, and agriculture’s relationship with the environment. USDA integrated two field/farm surveys in 2004, CEAP and ARMS, to extend its ability to assess the impact of working-land programmes beyond the realm of farm management practices and environmental outcomes, and to account for

Table 3. Model II estimated GEE coefficients for field-acreage allocation equations by field structural practice (technology), and by conservation programme participation [Model II: $(A_{j,p}) = f$ (normalized input prices, technology class, installation and socio-environmental variables)]

	Programme Non-Participants		Programme Participants	
Equation/Variable	Estimate	T-tests[b]	Estimate	T-tests
Wheat field acres planted (with):				
No structural practices:[a]				
Constant	5.0562*	3.95	6.0969*	3.95
N price	–5.7389	–0.40	–39.8077***	–1.58
Ag. wage	–0.9617*	–2.25	–0.8363	–1.28
Diesel price	3.7133	0.66	11.4316	1.13
Only infield structures:[a]				
Constant	4.3017	1.20	4.8924	1.40
N price	42.3335**	1.98	27.5670	0.67
Ag. wage	0.2694	0.30	–0.3750	–0.44
Diesel price	–16.0209**	–1.78	–5.7843	–0.49
Only field perimeter structures:[a]				
Constant	9.6799	1.23	10.7206	1.32
N price	–7.2329	–0.14	–34.8292	–0.04
Ag. wage	1.8047	0.55	–11.4288	–0.10
Diesel price	–34.9858	–1.11	82.5243	0.09
Both structural practices:[a]				
Constant	4.6438	1.04	5.6845	1.21
N price	24.0435	0.45	105.9105*	2.15
Ag. wage	3.2048	1.02	–2.5733	–0.75
Diesel price	–39.8850	–1.30	–6.5735	–0.25

Installation Dummy Variables		Estimate	T-tests
Installed in 2004	(Yes = 1)	–0.0904	–0.37
Installed within last 10 years	(Yes = 1)	0.0316	0.47
Installed prior to 1990	(Yes = 1)	0.1763*	2.37
Site-Specific Socio-Environmental Variables			
Farm tenure rate	(owned/operated acres)	0.1758*	2.26
Farm cropland acres	(acres)	0.0001*	9.04
Crop rotation	(Yes = 1)	–0.0519	–0.45
Gully erosion on field	(Yes = 1)	0.3023*	2.94
Field next to water body	(Yes = 1)	–0.1845	–1.47
Surface drainage	(Yes = 1)	0.3403*	2.28
Improve wildlife habitat	(Yes = 1)	–0.1079	–0.64

Log Likelihood Value (L_2) = 110,644,726

Source: 2004 CEAP-ARMS Phase II data, Economic Research Service, USDA.

Notes: [a] State average per unit prices (2004) for nitrogen ($/lb), agricultural wage ($/hr.), and diesel ($/gal.) were normalized using state average 2004 wheat price ($/bu.).

[b] Critical values for the t tests are 1.52 (***), 1.76 (**), and 2.14 (*) for the 15 %, 10 %, and 5 % significance levels, respectively. Standard errors were estimated using the delete-a-group Jackknife approach (Dubman, 2000).

other producer behavioural and economic factors. Development of CEAP-ARMS recognizes that producers may adopt conservation practices for reasons other than programme incentives. To isolate the role of conservation programmes, policy-makers might consider the relevance of other factors associated with the producers' decision to adopt various conservation technologies, while forgoing acres that could be used for crop production.

We used the 2004 CEAP-ARMS for wheat to first summarize the differences between conservation programme participants and non-participants, by farm-size class. The 2004 CEAP-ARMS Phase II data demonstrates that for farms growing wheat, differences exist between conservation programme participants and non-participants, and across farm-size types. While most wheat farms (in 2004) did not participate in USDA conservation programmes (on at least acres planted to wheat), higher-sales wheat farms participating in conservation programmes were larger, and operated more acres than their counterparts not participating in conservation programmes. On average, most wheat farms participating in a conservation programme reported less net farm income, with higher-sales non-participant wheat farms averaging 2004 net farm incomes over 9 times that for similar participating farm types. Agri-environmental characteristics also differed across farm types, suggesting the importance of accounting for site-specific environmental conditions when evaluating producer conservation practice decisions. In addition, the data reveals that higher-sales farms not participating in a conservation programme had adopted conservation land-management practices more intensively for 2004 wheat than did any other farm-size type for conservation programme participants as well as non-participants. Since these farms accounted for 40% of the 52.8 million wheat acres planted in 2004, they likely made the largest contribution to environmental benefits associated with the adoption of land-management practices on wheat acres in 2004.

To supplement these univariate comparisons, we then developed and estimated a cost-function based, crop-specific acreage allocation model of adoption of conservation structural practices. Wheat field acreage-supply equations were estimated for four conservation structure technologies and their installation on wheat fields, including wheat planted on fields with: (1) no structural practices (the counterfactual case), (2) only infield structures, (3) only field perimeter structures, and (4) wheat fields with both structural practices, for conservation programme participants and non-participants. Two versions of the model were estimated, with both empirical models accounting for the potential correlation between adoption choices. In the first model, field-level acreage allocation for wheat was evaluated as a function of relative input prices for nitrogen, agricultural wages, and diesel fuel, while accounting for alternative structural technology choices and for previous conservation structure installations (i.e., structures that may have been installed by previous landowners). In the second model, similar acreage-allocation equations were estimated, but with additional covariates to control for farm structure, field management, and environmental attributes.

Model II results demonstrated some degree of robustness compared with Model I results. Even so, while the performance of the relative price variables within the econometric models was modest, some insight was gained with respect to understanding the importance of controlling for farm and field-specific environmental information when gauging the extent to which relative input prices are correlated with decisions to allocate land to wheat production and/or conservation structures. Applying a cost-function acreage allocation model provided additional insight into producer decisions on the adoption of conservation structural practices in US wheat production.

Empirical model results also corroborated the univariate comparisons between conservation programme participants and non-participants, and the conservation structures they installed on their wheat fields. Both findings suggest that farm operators not participating in a conservation programme place more emphasis on adopting infield conservation structures, while conservation programme participants tend to adopt field perimeter structures, holding other factors constant. Most wheat producers, particularly those farms not receiving conservation programme payments, appear to recognize the productivity/profitability benefits of infield structures as sufficient to promote their adoption without programme incentives. However, it is likely that because the benefits from field perimeter conservation structures are more often off-site, programme incentives may be necessary to encourage their adoption.

From a policy perspective, estimates from the empirical models afford one the opportunity to evaluate a broader set of conservation impacts; in particular, differentiating producer response between conservation programme participants and non-participants for agricultural policies in the context of changes in relative input costs. Such evaluations add to environmental benefit/cost assessments of agricultural conservation policies by contributing to further understanding of the ‘green-box’ components of working-lands agriculture assessments (Aillery, 2006), and how they relate to operator decisions with respect to installation of conservation structures on farmland amidst input price uncertainty.

Comparing the results of two econometric specifications suggest that other factors besides production costs are also important with respect to understanding acreage allocation decisions between crop production and conservation structures. Not accounting for field/farm/environmental decision factors may under- or overestimate how producers make profit maximizing decisions with respect to installing conservation structures on cropland that could otherwise be used for commodity production, given changes in input and crop prices.

Finally, while conservation programme participants and non-participants may view field-level acreage allocation choices differently, policy makers are generally interested in aggregate impacts. Because the working-farmland acreage base is much larger for farms not participating in conservation programmes growing wheat, and because field perimeter structural practices can involve differential productivity/field-level cost effects and off-site benefits, programme incentives may play an important role with respect to encouraging adoption of working-land conservation structures.

Notes

1. The views expressed are the authors’ and do not necessarily represent those of the Economic Research Service, the US Department of Agriculture, the University of Tennessee, or the University of Delaware.
2. USDA’s National Resources Inventory (NRI) is a longitudinal survey of soil, water, and related environmental resources designed to assess conditions and trends on non-federal US lands. Data is collected for a field (or primary sampling unit (PSU)) associated with specific latitude/longitude points. For more information, see http://www.nrcs.usda.gov/technical/NRI/.
3. For more information on ARMS, see the website: http://www.ers.usda.gov/Briefing/ARMS, and for CEAP, see the website: http://www.nrcs.usda.gov/technical/nri/ceap/index.html.
4. CEAP-ARMS states for 2004 wheat included Washington, Oregon, Idaho, Montana, North Dakota, South Dakota, Nebraska, Colorado, Kansas, Oklahoma, Texas, Minnesota, Missouri, Illinois, Michigan, and Ohio.
5. The ARMS Phase 3 response rates vary by year, but usually average about 60–67% of Phase 2 sample completions. ARMS Phase 3 weights are appropriately re-calibrated by USDA’s National Agricultural Statistics Service.

6. In addition to HELCC, conservation financial assistance programmes included in the definition for 'participants' involved the following programmes: Conservation Security (now Stewardship) Program (CSP), Environmental Quality Incentives Program (EQIP), Klamath Basin Water Conservation Program, Ground and Surface Water Conservation Program, Wetlands Reserve Program (WRP), Wildlife Habitat Incentives Program (WHIP), Conservation Reserve Program (CRP), Farmland Preservation Programs, and State Cost-Share Programs.
7. Phase II data was used to define conservation programme participants versus non-participants because the CEAP-ARMS Phase II conservation programme participation information applies to field-level practices, while the Phase III programme participation information applies to the whole farm, but not necessarily to the Phase II conservation practice data linked to the NRI environmental data.
8. The aggregate farm typology we used was used by Lambert *et al.*, 2007b. The full ERS farm typology is defined at http://www.ers.usda.gov/Briefing/FarmStructure/glossary.thm#typology.
9. Gully erosion and the USLE are field-specific land-quality indicators. The USLE is a computed measure of expected soil loss (in tons/acre/year) from the field given its general environmental characteristics, identified at an NRI point for the field. However, gully erosion occurring on a field is a survey-based producer-specified indicator of erosion severity.
10. The CEAP-ARMS data suggests that there were about 347 000 wheat farms with HEL acres in a wheat field, accounting for about 15.8 million wheat acres, with conservation programme participants accounting for 61% of these acres.
11. Full utilization for the traditional probabilistic framework is a necessity because technology allocation shares must sum to 100% of the assumed fixed landholdings (Just & Zilberman, 1983).
12. For information on empirical model structure, its design matrix and parameter estimation, contact the authors at schaible@ers.usda.gov, dlamber1@utk.edu, or ckim@ers.usda.gov.
13. For HEL land, conservation compliance is mandatory, that is, all HEL land is required to have a conservation plan. While there may be some differences in adoption behaviour between mandatory and voluntary participants, the CEAP-ARMS data does not differentiate these differences. Therefore, we restrict our modeling to address only participant versus non-participant behaviour.
14. Use of GEE to estimate separate acreage-supply equations by technology does account for differences between adopters and non-adopters, which is a special case of sample selection problems. However, self-selection problems for a second-level joint probability distribution are not modeled here (due to a lack of commercially available software packages capable of addressing these issues for such a complex two-level system). Nonetheless, even in the presence of sample selection bias or other issues leading to endogeniety problems, general associations between variables and responses can still be appreciated (Cameron & Trivedi, 2005). Problems arise when the research aims to go beyond associations and establish causality. Lichtenberg (JARE, 2004) and Cooper and Keim (AJAE, 1996) also acknowledged this issue and recognized an appropriate need to make similar trade-offs.
15. First, the structural technology class variables are a requirement of the estimable functional form (see equation 9) that isolate technology-specific effects for the p^{th} programme participation class. Second, because for some fields, practices (like terraces) may have been installed with incentive payments when the land was owned by a previous landowner, we at least in part, control for this possibility by adding variables to account for the time of installation of the structural practice on the field.
16. Per-unit prices for nitrogen, agricultural wages, diesel fuel, and output (for wheat) reflect state-average prices for 2004 acquired from USDA's National Agricultural Statistics Service (as summarized by USDA's Economic Research Service, 2006).
17. While not available in CEAP-ARMS, unit costs for selected conservation practices funded by USDA's EQIP are summarized in an ERS data product (at http://www.ers.usda.gov/Data/eqip/). These costs can range from \$1.06 per foot for terraces to \$3764.82 per structure for a grade stabilization structure.

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