Agricultural Sedimentation Impacts on Lakeside Property Values

Somskaow Bejranonda, Fred J. Hitzhusen and Diane Hite

A hedonic pricing model is developed to estimate the effects of policies to control agricultural sedimentation on lakeside property values at 15 Ohio state park lakes. Using an LA/AIDS demand system, we estimate changes in social welfare that result from upstream soil conservation practices and/or lake dredging activity, while holding other property characteristics constant. Policy simulation results suggest that lakeside residents generally have a higher willingness to pay on an annualized basis for sediment reduction from upstream soil conservation than for lake dredging. This has important implications for soil conservation policy, particularly in targeting improvements in the economic efficiency of the Conservation Reserve Program.

Introduction

Soil erosion from agriculture and the downstream impacts of sedimentation continue to be an important environmental problem in the U.S. and elsewhere. The Conservation Reserve Program (CRP) in effect since the 1985 Farm Bill in the U.S. has reduced gross erosion from agriculture by paying farmers to remove the most erosive lands from row crop production. However, under the 1996 Farm Bill, this program is being downsized in terms of acreage covered, and the average payment per acre has been reduced to control program costs. Some fear that these policy changes will increase soil erosion and downstream sedimentation.

Earlier studies provide national aggregate off-site cost estimates for soil erosion. Clark, Havercamp and Chapman estimate the total annual off-farm costs for all agricultural erosion sources to range from \$3–\$13 billion with a point estimate of \$6.1 billion, of which \$2.2 billion was attributable to cropland erosion (in 1980 dollars). Loss of recreational value accounted for the largest share of costs, nearly 33% with boating being the largest subgroup. Other high impact recreationists or users and their percent of total costs included municipal and industrial (14.8%), water storage facilities (11.3%) dredging (8.5%), and preservation values (8.2%). Of all erosion sources, cropland comprises the largest share at 38%. Ribaudo's (1986) reanalysis of Clark et al.'s estimates resulted in a point estimate at \$7.1 billion. Thus, the costs are not trivial.

Sedimentation caused by agricultural soil erosion is a major source of damage and economic loss throughout the crop producing regions of the U.S. Our analysis focuses on lakeside property values in reservoirs and lakes in Ohio which, as a transition state in terms of physical and demographic characteristics, represents conditions found in the Corn Belt, Appalachia and the Northeast regions of the U.S. Farmland covers approximately 15.4 million acres of land area in Ohio, but it is the 77% of farmland under cultivation that contributes most of the sediments that eventually damage waterways. Two studies in particular have estimated annual agriculturally related off-site soil erosion costs in Ohio. In 1983, the Soil and Water Division of the Ohio Department of Natural Resources (ODNR) estimated direct off-site cost of removing soil erosion sediment in Ohio at \$160 million/year. In addition, the Ohio Alliance for the Environment (1988) estimated the annual cost of removing sediment from Ohio's lakes, waterways, harbors, and water treatment plants at \$162 million. Both of these studies focused on the accounting costs of a clean up which do not necessarily account for the full social costs of erosion.

Macgregor (1988) found that sedimentation at 46 Ohio State park lakes resulted in per-boater

Somskaow Bejranonda is an assistant professor with the Faculty of Economics, Kasetsart University, Bangkok, Thailand. Fred J. Hitzhusen is a professor with the Department of Agricultural, Environmental and Development Economics at the The Ohio State University, and Diane Hite is an assistant professor at the Mississippi State University Department of Agricultural Economics. We would like to acknowledge the valuable assistance of professors Donald Haurin and Alan Randall at Ohio State University in this research effort. We would also like to thank two anonymous referees whose insights helped to improve this manuscript.

losses to non-resident recreationists ranging from less than $0.01 to $11.95 per ton of sediment, with an average of $0.49 per ton of sediment. However, this research did not capture the impact of sediment on lakeside residents' property values. Based on anecdotal evidence from state park rangers and others, we hypothesize that residents adjacent to the lakes will suffer welfare losses if sediments render the lakes to be less desirable for boating, fishing, swimming, and any other activities due to shallow depths and/or change in water quality. Scenic views may also be lost due to increases in weeds and algae. These impacts lead to a decline in both property and recreational values for lakeside property owners.

The impacts of sedimentation on recreation and property values have been recognized and addressed by the state of Ohio. For example, the Division of Watercraft of the Ohio Department of Natural Resources allocates almost $2 million annually for dredging lakes; this constitutes almost one-seventh of the total budget of the Waterways Safety Fund. The Waterways Safety Fund consists of boater registration fees paid every three years (depending on factors such as size and power of the boat) and a one-half of one percent tax on marine gasoline. Thus, costs of dredging are borne by individuals who use the lake (primarily boaters), but not necessarily by those who live on the lake. Furthermore, upstream farms are the major source of sediment run-off, but farmers pay for dredging only if they boat, and are not required to directly compensate downstream users. The question of who should be responsible for compensating downstream users for soil erosion damages continues to be debated.

A U.S. Soil Conservation Service study (1990) suggests that there are two ways to reduce accumulation of sediment in the lakes. The first method entails dredging the lake to directly remove accumulated sediment. The second procedure is to control upstream soil erosion by employing soil conservation practices such as conservation tillage and no-till. The major objective of this study is to measure the social costs of sediment accumulation to lakeside property owners, and to estimate the benefits that are realized from dredging and upstream soil conservation practices. The benefits from the two policies differ in that dredging directly reduces sediment in specific areas of a lake and thereby increases depth, while changing upstream soil conservation practices reduces the sediment entering the lakes without increasing the depth.

We use a two-stage hedonic price model (HPM) to analyze the welfare impacts of these policies on lakeside property values at state park lakes, including both vacation and year round residences. From the empirical model, we estimate the implicit price of a change in environmental quality associated with different sedimentation reduction programs, thus enabling us to estimate the social benefits accruing from a given policy.

The use of the HPM in a benefit-cost framework is well established. Since the formalization of hedonic theory by Rosen (1974), a number of authors have used the HPM to estimate implicit prices and demand for housing characteristics, such as Linneman (1981), Parsons (1986), and Quigley (1984). An important branch of this literature deals with the problems of estimating nonmarginal changes in implicit prices, such as in Bartik (1987, 1988), Brown and Rosen (1982), and Epple (1987). A growing literature has used the HPM to measure welfare changes in implicit markets for environmental quality, for example, Mendelsohn (1984), Nelson (1978), Palmquist (1988), and Palmquist, Roka and Vukina (1997). We use a complete demand system technique in a way similar to Driscoll, Alwang and Dietz (1994). The advantage of this methodology is that it allows us to recover parameters of the empirical indirect utility function from which we directly calculate compensating variation measures of welfare changes.

Our paper is organized as follows. First we estimate the first-stage of the hedonic price function from which we obtain implicit prices for characteristics of lakeside properties such as structural, community, and ambient environmental quality. Then, we use Deaton and Muellbauer's (1980) Linear Approximate/Almost Ideal Demand System (LA/AIDS) to estimate the second stage demand equations for structural and environmental characteristics of lakeside properties. Finally, the compensating variation (CV), which we derive directly from the LA/AIDS indirect utility function, is used to estimate lakeside residents' willingness to pay for improved environmental quality at the lakes. The policies we examine include increasing the depth of the lakes through a dredging program and reducing the rate of sediment inflow entering the lakes by employing upstream soil conservation practices, as well as various combinations of dredging and soil conservation.

Methodology

Sampling and Data

Several criteria were used to select the Ohio State park lakes for this study. First, lakes with a minimum of 100 water surface acres were chosen, and private residences within 4,000 feet of the lake perimeter were included in the sample frame.[1] Second, the lakes are located throughout the state in areas that have different levels and sources of soil erosion that are broadly representative of not only Ohio, but other parts of the Eastern and Midwestern U.S. Lastly, the lakes have different horsepower (HP) regulations. A total of 15 state park lakes were chosen based on the foregoing criteria, and were categorized into two groups based on HP regulation. Eight of the lakes have HP greater than 10, including Buckeye Lake, Caesar Creek, Grand Lake St. Marys, Indian lake, Rocky Fork, Lake White, Mosquito Lake, and Lake Loramie. The second group of lakes that have HP equal to or less than 10 are Harrison Lake, Madison Lake, Lake Logan, Kiser Lake, Guilford Lake, Wolf Run, and Jackson Lake. The 15 state parks lakes are divided into two groups (or markets) because we hypothesize that lakeside property rents between these two markets differ depending on property characteristics as well as activities available at the lakes. For example, people who like to water ski will reside at the lakes that have HP greater than 10, while those who enjoy sailing or fishing will be more likely to live at the lakes that do not allow higher HP.

Once the study sites were determined, a cross-sectional data set of assessed values and structural characteristics of 2,677 randomly selected lakeside properties were gathered from county auditors' offices. A total of 2,297 observations were drawn from lakes with HP limits greater than 10, and 380 observations were drawn from lakes with HP limits less than 10.[2] The property locations were charted on area topographic maps and we were thus able to add locational variables, such as distance of a property to a lake and miles to the nearest metropolitan center. In addition, county level demographic characteristics were obtained through U.S. Census data.

Data on structural, locational, community and environmental characteristics were used as independent variables in the first stage estimate of the HPM. Structural characteristics include: lot size in sq. ft. (LOT); the size of the house in sq. ft. (DWELL); number of rooms (RM); number of full-baths (FB) and half-baths (HB); age of the building in years (OLD); dummy variables for air-conditioning (AC), heat (H), basement (BS), garage (GAR), fireplace (FP); and dummy variables for structural improvements such as patio and deck (IMP). Also included is a measure of the nearest distance between a property and lake in feet (DSTL). In addition, community characteristics of the properties and lakes were included such as county population (POP), the distance from property to the nearest central business district in miles (CBD), and the unemployment rate in the county where the lake is located (UMEMP).

The variables of most interest, the environmental characteristics of the lakes, were added to the data set and include the average depth[3] of the lakes in feet (ADEP). ADEP can be viewed as a variable that partially characterizes the type of lake on which a given property is located. We view annual sediment accumulation[4] (STPS), and average annual sediment dredged in cubic yards per acre foot per year (DRED) as policy variables; that is, it is through dredging and sediment inflow controls that changes to the status quo levels of the lakes (ADEP) can be impacted. It should be noted, however, that the way in which these variables impact lake depth differs significantly. Dredging activity impacts specifically chosen areas of a lake, especially lake-access points and channels. On the other hand, physical forces, such as weather and hydrology govern sediment inflow and deposition. The result is that the ADEP, DRED and STPS are fairly independent since ADEP is a physical variable, measured on levels for a whole lake, DRED is a strategic variable determined by public choice, and STPS is related to both physical characteristics of a watershed and farming practices. Dredging activities will significantly impact small areas of a lake, and cannot realistically have a major impact on the average depth of a large body of water, such as the lakes in this sample. In addition, STPS and ADEP are probably not very interrelated because the lakes are located in different areas of the state where the size, volume, and terrain are very different, resulting in varying degrees of sedimentation inflow and impact on depth. Even in the smallest lakes, the annual sediment inflow is small compared to overall lake volume and therefore will not significantly affect average depth.

The dependent variable consists of the annual

[1] 4,000 feet was chosen as a cutoff since the majority of lakeside residences are clustered within this distance. The lakes are in rural areas, and land beyond 4,000 feet generally reverts back to agricultural use.

[2] Because sales data are typically sparse for such vacation homes, assessed values and the characteristics were used rather than actual transactions prices. Following a procedure used in the urban economics literature, a subset of actual sales data was collected, and a predictive model estimated in order to adjust for the differences between assessed prices and actual sales prices (see Bejranonda, 1996, for details). This model was the one actually used in calculation of implicit marginal prices for property characteristics.

[3] Larger lakes had multiple variables for average depths as measured at several locations since there is considerable variation in lake depth depending on factors such as proximity to streams, agricultural fields, etc.

[4] Measured as a percent of the lake volume or sediment inflow.

rental equivalent of the property. To convert total housing value into an annual rental rate, we rely on asset value theory which suggests that the price of a house is equal to the sum of the net present value of housing services over an infinite time horizon, i.e. $P = \Sigma_{t=0}^{\infty} R/(1 + i)^t$. In the preceding, t is the year, P is the property price (or market value, in this case), R is the annual rent for housing services, and i is the discount rate. From the above expression it is evident that the annual rental rate R is given by $i \cdot P$, or rate of interest times total house price or value; we adopt an 8% discount rate. The reason for using a rental rate rather than the actual property value is quite simple: all of the policy variables are couched in annual terms, so that the rental equivalent is necessary to calculate appropriate welfare measures. See table 1 for descriptive statistics of the variables included in the first stage estimates.

First Stage Estimate

The Hedonic Pricing Model (HPM) has gained great popularity for use in measuring the welfare impacts of changes in environmental quality. In the HPM, the implicit prices of property characteristics, including environmental quality are embedded in the transaction price and/or property rent value. We theorize that property rent should be a function of the structural, community, and environmental characteristics of the properties. The regression model used is given by

$$(1) \quad \log(\text{RENT}) = a_0 + a_1 \log(\text{LOT}) + a_2\,\text{DWELL} + a_3\,\text{DWELLSQ} + a_4\,\text{OLD} + a_5\,\text{RM} + a_6\,\text{FB} + a_7\,\text{HB} + a_8\,\text{AC} + a_9\,\text{H} + a_{10}\,\text{GAR} + a_{11}\,\text{BS} + a_{12}\,\text{IMP} + a_{13}\,\text{FP} + a_{14} \log(\text{DSTL})$$

Table 1. Summary Descriptive Statistics of Variables Used in Hedonic Model and Estimated Coefficients of the First Stage Limited and Unlimited HP Markets

	Limited HP Market (HP ≤ 10)			Unlimited HP Market (HP > 10)		
Variable	Mean	Coeff. Estimate	t-value	Mean	Coeff. Estimate	t-value
Dependent Variable						
RENT	4,480.74			6,630.94		
Regressors						
Intercept		0.5412	0.718		7.7607***	53.264
LOT	28,939	0.2087***	5.587	15,327.35	0.0756***	6.310
DWELL	930.43	0.0022***	8.099	1,188.85	0.0008***	14.567
DWELLSQ		-3.1E-7***	-5.684		-9E-8***	-4.65
OLD	32.28	-0.0028*	-1.868	35.85	-0.0042***	-12.407
RM	4.58	0.0604***	3.071	5.09	0.0526***	7.700
FB	0.92	0.0368	0.536	1.15	0.0982***	5.109
HB	0.39	-0.0522	-0.667	0.31	0.0003	0.017
AC	0.13	0.0328	0.401	0.21	0.1212***	5.936
H	0.83	0.0579	0.856	0.83	0.1717***	8.318
GAR	0.36	0.0026	0.050	0.46	0.1736***	10.691
BS	0.49	0.3417***	6.267	0.44	0.0427***	2.543
IMP	0.76	0.2140***	3.659	0.65	0.0880***	4.863
FP	0.37	0.0665	1.262	0.35	0.1377***	8.182
DSTL	563.12	-0.0909***	-4.781	552.22	-0.1838***	-26.006
POP	5,017.46	0.0003***	9.004	5,914.86	5.7E-6**	1.984
CBD	8.48	0.1121	0.778	9.20	-0.0190	-0.814
UNEMP	7.84	-0.0211	-0.580	6.72	-0.0373***	-5.397
ADEP	7.93	0.0875***	6.432	6.35	0.0238***	4.693
ADEPSQ		-0.0007*	-1.775		-0.0001***	-5.194
STPS	0.28	-0.1545***	-3.067	0.13	-0.1104***	-9.812
DRED	44.30	0.1812***	5.568	7.52	0.1085***	10.076
	R^2 = 0.7831	Adj R^2 = 0.7704		R^2 = 0.6938	Adj R^2 = 0.6910	
	F-Statistic = 61.542	N = 380		F-Statistic = 245.440	N = 2297	

*Significant at 0.10 level.
**Significant at 0.05 level.
***Significant at 0.01 level.

$$+ a_{15}\,\text{POP} + a_{16}\,\text{CBD} + a_{17}\,\text{UNEMP} + a_{18}\,\text{ADEP} + a_{19}\,\text{ADEPSQ} + a_{20}\log(\text{STPS}) + a_{21}\log(\text{DRED}) + \varepsilon$$

where the α_i's are estimated coefficients and ε is the error term, and log represents the natural logarithm. The model specification is a mixed log-linear model that arises from the observation that the variables that represent price, lot size, distance to lake, net annual sediment inflow, and the annual dredging rate appear to be log-normally distributed. Based on various criteria, such as F-tests and explained variation, this specification out performed others.

Equation (1) is estimated separately for the limited HP (HP $\leq$ 10) and unlimited HP (HP > 10) markets utilizing ordinary least squares. The ADEP and ADEPSQ coefficients are hypothesized to be positively and negatively related to price, respectively, i.e., property rents should increase with the lake depth at a decreasing rate; this is so because increased depths not only provide increased possibilities for recreational activities, but may exhibit decreased turbidity as well.[5] In addition, if the rent variable is exponentiated, then the marginal implicit price (MIP) of ADEP is given by $\partial\text{Rent}/\partial\text{ADEP} = (\alpha_{18} + 2\cdot\alpha_{19}\cdot\text{ADEP})\cdot\text{Rent}$; this condition suggests that increasing depths will have a positive effect as long as ADEP > $-\alpha_{18}/2\cdot\alpha_{19}$. STPS is expected to have a negative sign, meaning that higher rates of sediment inflow entering the lakes result in lower property rents. The coefficient of DRED is expected to have a positive impact on property rent, i.e., the greater the annual sediment dredged from the lakes, the higher the property rent.

The coefficients (α_i's) derived from equation (1) are used to calculate the marginal implicit prices for each horsepower market;[6] the marginal implicit prices are ultimately used as dependent variables in the second stage estimate of marginal willingness to pay.

Second Stage Estimate

The Almost Ideal Demand System (AIDS) we use to estimate demand for property characteristics was introduced by Deaton and Muellbauer (1980), and subsequently used in the hedonic framework by Parsons (1986) and others. The budget share form of the model is given by:

$$(2)\quad W_i = \alpha_i + \Sigma_j\,\gamma_{ij}\log P_j + \beta_i\log(Y/P)$$

where P is a price index defined by

$$(3)\quad \log P = \alpha_o + \Sigma_k\,\alpha_k\log p_k + 1/2\,\Sigma_j\Sigma_k\,\gamma_{kj}\log p_k\log p_j.$$

Y_i in equation (2) is total expenditure on property characteristics from the first stage model; in this case, Y_i represents the total price of the property. The q_i are quantities of a given housing characteristic at each property and p_i represents the i^{th} characteristic's implicit price.

The non-linearity of the full AIDS model presents estimation difficulties. Therefore, we use the linear approximation of the demand system, which incorporates the Stone Price Index defined as:

$$(4)\quad log\ P^* = \Sigma_j\,W_j\log p_j \quad j = 1, 2, \ldots, n.$$

Then the LA/AIDS model that we use for our estimates is derived from substituting equation (4) into (2), and can be written as:

$$(5)\quad W_i = \alpha_i + \Sigma_j\,\gamma_{ij'}\log p_j + \beta_i\log(Y/P^*) + \nu_i$$

where W_i is the budget share spent on the i^{th} good and equals p_iq_i/Y_i, the total expenditure of the household; α_i, γ_{ij}, β_i are the parameters to be estimated; and ν_i is the disturbance term.

In order to use the LA/AIDS to estimate the demands for housing and property characteristics, we assume the following:

1. Housing markets are segmented by HP regulation and are in equilibrium.
2. The supply of housing and property characteristics is exogenous and varies across markets.
3. Household preferences are weakly separable in
   a. housing and property characteristics and all other goods;
   b. HP regulation and all other housing and property characteristics; and
   c. housing and property characteristics included in the analysis and characteristics excluded from the analysis.
4. The hedonic price functions are non-linear.

Based on assumptions (3) and (4) and equations (2)–(5), the empirical model for the LA/AIDS is:

$$(6)\quad W_i = \alpha_i + \Sigma_j\,\gamma_{ij}\log P_j + \beta_i\log\left(\frac{X_H^*}{P^*}\right)$$

[5] We attempted to include a measure of turbidity in the regressions, but it was found to be insignificant, perhaps because the measures were not consistently gathered across the lakes in the sample.

[6] Obtained in the usual manner by taking the first derivative of Eq 1 with respect to each characteristic.

where α_i, γ_{ij}, and β_i are parameters to be estimated. In equation (6), the p_j's represent the empirical MIPs for housing characteristics derived from the non-linear hedonic price functions of the limited and unlimited HP markets. The MIPs consist of the derivatives of the hedonic price function with respect to each property characteristic. The variable X^*_H is the 'mythical' adjusted expenditure based on the nine housing and property characteristics in the first stage estimate. X^*_H is calculated for each household in the sample by summing the property characteristics times marginal implicit price from the first stage regression. That is, $X^*_H = \Sigma_{i=1}^{9} p_{iH}q_{iH}$. W_i is the budget share for the i^{th} housing and property characteristic, where $i = 1, 2, \ldots, 9$ represents characteristics of lot size, dwelling size, the number of rooms, the number of full-baths, average depth of the lake, the amount of sediment dredged from the lake, the accessibility to the lake (or the inverse distance from property to the lake), and environmental quality (or the inverse rate of sediment inflows), and an index variable of structural amenities respectively.[7] The definitions of the last two variables are discussed in the next section.

We assume that there are two ways that changes in environmental quality take place. First, dredging can be used to increase average depth of the lake over time, and second, the rate at which sedimentation accumulates in a lake can be lowered through upstream or off-site soil management practices that decrease sediment inflows. In addition to investigating impacts of single policies, we address the combined effects of offsite soil management with dredging. We use a direct measure of welfare change of environmental quality by calculating empirical compensating variation (CV). CV is calculated to evaluate the lakeside property owners' willingness to pay for increased levels of environmental quality at the lakes that result from increasing average depth of the lakes and/or decreasing the sediment inflow entering the lakes. Equation (7) gives the algebraic representation of CV for the LA/AIDS model as developed by LaFrance (1991).

$$(7)\quad CV = X_H^0 - \exp\left(\prod_i \left(\frac{\text{PADEP}^1}{\text{PADEP}^0}\right)^{\beta_{\text{ADEP}_i}} (\log X_H^0 - \log P^{*0}) + \log P^{*1}\right).$$

Here, PADEP^0 is the MIP for the original average depth of a lake, and PADEP^1 is the MIP for the average depth that results from dredging projects at the lakes. A similar equation holds for the marginal implicit price for reduced sediment inflows from conservation practices as given by the variable STPS. X_H^0 represents the adjusted total expenditure that a property owner spends on lakeside property given the initial lake depth, and $\log P^*$ is the estimated Stone Price Index under the initial lake depth (0 superscript) and increased depth (1 superscript).

In this paper, we first calculate predicted implicit prices under the baseline scenario and then recalculate them by varying the policy (ADEP and STPS) variables. Thus we are able to calculate CV in order to simulate changes in welfare to lakeside residents of a dredging project that removes sediment, a soil management program that reduces soil inflows or combinations of both. We assume that dredging increases average lake depth by 0.5, 1.5, and 2.0 feet, respectively; the depth values were chosen because ODNR officials suggested that dredging the lakes more than 3 feet would cut into the original base of the lakes at many locations. We estimate benefits from soil conservation practices to downstream lakeside residents by assuming that under a corn-soybean-wheat rotation, changing from a conventional to reduced-till soil management system will reduce the rate of sediment inflow by 50% and changing to a no-till practice will reduce sediment inflow by 75%. These estimated changes in sediments inflow are based on discussions with soil scientists at Ohio State University and USDA. These scientists were asked to suggest realistic sediment inflow reductions for the soils and topography in the areas of the 15 lakes. Equation (7) is also used to produce estimates using these criteria.

Results

The system of share equations represented by equation 6 was estimated using 3SLS. Horsepower regulations are considered to be an exogenous factor that can be used to identify the two markets in this research; to test this hypothesis, an F-test was performed to determine whether the characteristics of lakeside properties at low HP lakes were significantly different from those at unlimited HP lakes. The results confirm that the 15 state park lakes can be categorized into two markets, which represent the limited (HP $\leq$ 10) and unlimited (HP $>$ 10) HP markets. From table 1, the limited and unlimited HP markets have adjusted-R^2's of 0.77 and 0.69, respectively. Most of the variables in both markets are statistically significant and have

[7] Amenities included in are central AC, central heat, garage, basement, fireplace, and structural improvements.

the hypothesized signs, including the environmental characteristics: lake depth, sedimentation rate, and annual dredging. Note that for the lake depth variable, ADEP, increasing depth has a positive impact on price until depth reaches 62.5 feet for low HP lakes, and 119 feet for unlimited HP lakes. The results indicate that for deeper lakes, sediment impacts are lower, and furthermore, that when dredging of deeper lakes is undertaken, property rents increase with increases in depth.

By comparing the marginal implicit price at the global mean (i.e., calculated at the mean of the full data set), the results in table 2 show that environmental characteristics will have more impact on the limited HP than the unlimited HP market. This is probably because the lakes within the limited HP market are smaller lakes located in areas with higher rates of sediment inflow than lakes within the unlimited HP market. It is interesting to note that the limited HP lakes are deeper on average than the unlimited HP lakes, but tons dredged in limited HP lakes are nearly six times greater than in unlimited HP lakes. This is a result of the fact that the amount of sediment dredged as a percent of lake volume within the limited HP market is higher than in the unlimited HP market because of the smaller water area in the limited HP lakes. In both markets, coefficients of the average depth variable confirm that property rents increase at a decreasing rate with increases in average depth of the lakes; however, as expected, the effect is greater in the limited HP lakes. Judging from the coefficients for STPS, sediment inflows have a larger negative impact for limited HP lakes than for unlimited HP lakes, which can once again be explained by the fact that the limited HP lakes are smaller than the unlimited HP lakes.

We limit our reporting of the results of the LA/AIDS estimates of share demands in table 3 to the equations for environmental characteristics, ADEP, ISTPS (inverse of sedimentation rate),[8] and DRED. PLOT, PDWELL, PRM, PFB, PAMEN, PDSTL, PADEP, PSTPS, and PDRED represent the estimated marginal implicit prices for lot size, dwelling size, amenities, distance from lake, average lake depth, sedimentation inflow and dredging, respectively. Compensating variation (CV) which is the lakeside residents' willingness to pay (WTP) for improved environmental characteristics at the lakes is calculated by using the formula from equation (7). Table 4 demonstrates that lakeside residents at the limited HP lakes (HP $\leq$ 10) have higher willingness to pay per acre foot of sediment removed and for reduced tillage induced decreases in the rate of sediment inflow into the lakes than

[8] In the second stage estimate we use inverse sedimentation rate as a positive indicator of environmental quality.

Table 2. Estimated Implicit Marginal Prices for Environmental Characteristics

	Implicit Marginal Prices Calculated at Global Mean	
Variable	Limited HP	Unlimited HP
AverageDepth	$445.11	$178.15
Sediment Inflows	−5,855.05	−5,831.160
Dredging	80.85	67.47

Table 3. Estimated Share Demand Equations for Environmental Characteristics from LA/AIDS Model—Homogeneity and Symmetry Restrictions Imposed

	Characteristic Share		
Dependent Variables	ADEP	ISTPS[a]	DRED
Intercept	0.122***	0.198	0.169***
PLOT	0.012	−1E-5***	0.0001
PDWELL	0.031***	0.011***	0.004***
PRM	0.060***	−0.005***	−0.001***
PFB	−0.004**	−0.009***	−0.003***
PAMEN	0.001	−0.007***	0.002***
PDSTL	0.002***	−0.001***	−0.001***
PADEP	−0.122***	0.011***	0.008***
PSTPS	0.011***	−0.0002	−0.0001***
PDRED	0.008***	−0.0001	−0.008***
Expenditure	0.021***	−0.011	−0.013***

*Inverse of sedimentation rate.
**Significant at 0.05 level.
***Significant at 0.01 level.

Table 4. Average Benefit Estimates from Changing Average Lake Depth and Rate of Sediment Inflow per Acre-Feet of Sediment Removed

		Welfare Measure ($)/Acre-feet of Sediment Removed	
Increasing ADEP (feet)	% Change in STPS	Limited HP Market	Unlimited HP Market
0.5		5.1865	0.1529
1.5		5.1887	0.1532
2.0		5.1839	0.1532
	50%	85.1197	23.2166
	75%	115.9008	31.6747
0.5	50%	6.7645	0.3296
1.0	50%	5.6025	0.2106
2.0	50%	5.4454	0.1956
0.5	75%	8.7071	0.5413
1.5	75%	6.3440	0.2854
2.0	75%	6.0322	0.2531

Table 5. Benefits Per Acre-Foot of Sediment Removed by Changing Average Depth of Lake and Reducing the Rate of Sediment Inflow

	Benefit ($)/Acre-Foot of Sediment Removed				
	Increasing ADEP (feet)			% Change in STPS	
Lake	0.5	1.5	2.0	50%	75%
Guilford L.	3.7008	3.6929	3.6848	125.5111	171.1935
Harrison L.	9.8501	9.9348	9.9644	96.2951	132.1008
Jackson L.	0.5435	0.5346	0.5297	6.2530	8.5645
Kiser L.	5.0200	5.0442	5.0501	206.5446	281.6765
Logan L.	5.5172	5.5303	5.5309	97.1821	132.2841
Madison L.	14.2017	14.3311	14.3785	96.7835	131.8663
Wolf Run	2.7362	2.5217	2.4132	319.9989	434.9351
Limited HP	**5.1856**	**5.1887**	**5.1839**	**85.1197**	**115.9008**
Buckeye L.	0.2461	0.2394	0.2394	5.9322	8.6867
Caesar C.	0.1008	0.0987	0.0977	8.5148	11.6159
Grand L. St.	0.0510	0.0511	0.0512	11.7051	16.2407
Indian L.	0.1732	0.1737	0.1740	22.2746	31.0991
L. Loramie	0.5365	0.5377	0.5382	220.2547	308.4172
L. White	1.6340	1.6364	1.6373	110.7026	168.6167
Mosquito L.	0.0821	0.0817	0.0815	26.1506	38.0314
Rocky Fork	0.2019	0.2008	0.2002	39.7651	49.8141
Unlimited HP	**0.1529**	**0.1532**	**0.1532**	**23.2166**	**31.6747**

those who live at the unlimited HP lakes (HP > 10). This is because most of the limited HP lakes such as Lake Logan, Kiser Lake, Guilford Lake, and Wolf Run have not previously been dredged, and thus lakeside residents are willing to pay more per acre foot of sediment removed to obtain an increased depth at these lakes. However, lakeside residents have higher willingness to pay per acre-foot of sediment reduction by reducing the rate of sediment inflow through upstream soil conservation practices than by increasing the average depth of the lakes through dredging; this may be partially due to a reduction in turbidity that accompanies sedimentation reduction. It should be noted here that sediment inflows translate into potentially significantly varying depth impacts on lakes of different sizes. While dredging affects the depth of all lakes uniformly, sedimentation impacts depend on local soil characteristics as well as lake volume and sedimentation disposition patterns; this leads to quite different CV estimates for soil conservation vs. dredging policies.

The results show that a policy combining dredging and upstream soil conservation practices results in higher benefits to lakeside residents than if only a dredging project is employed, and are also higher at the limited HP lakes than the unlimited HP lakes, depending on lake volume. WTP, as measured by CV, increases with increased levels of soil conservation, and although positive, WTP for dredging actually decreases with increased dredging activity. This may be a result of the fact that dredging equipment may intrude on recreational activities. Furthermore, once farmers make a fixed investment in equipment that reduces sediment, benefits will continue to accrue into the future, and the mode of providing the benefit does not involve potentially intrusive on-site activity.

Tables 5 and 6 show the breakdown of estimated benefits reported in table 3 as experienced by lakeside residents at each lake location under dredging and/or upstream soil conservation practices. Among the limited HP lakes, lakeside residents at Madison Lake gain the highest benefits in terms of property rent if dredging or the combination procedure are implemented. Alternatively, lakeside residents at Wolf Run will gain more benefit in terms of increases in property rent if only upstream conservation practices are implemented. Among the unlimited HP lakes, lakeside residents at Lake White achieve higher benefit gains under dredging or the combination project, whereas lakeside residents at Lake Loramie enjoy higher benefits when only upstream soil conservation practices are employed.

ODNR has engaged in annual dredging that is ongoing currently at Buckeye Lake, Indian Lake, Lake Loramie, Grand Lake St. Marys, and Rocky Fork, even though the benefits received by lakeside residents at these locations are less than those in the limited HP lakes. This result can be partially explained by a study conducted by Lehman et al.

Table 6. Benefits Per Acre-Foot of Sediment Removed by Combining Changes in Average Depth of Lake and Reducing the Rate of Sediment Inflow

	Benefit ($)/Acre-Foot of Sediment Removed					
	Rate of Sediment Inflow Reduced by 50% and Increasing ADEP (Ft)			Rate of Sediment Inflow Reduced by 75% and Increasing ADEP (Ft)		
Lake	0.5	1.5	2.0	0.5	1.5	2.0
Guilford L.	4.5173	3.8813	3.7913	5.5703	4.2842	4.1124
Harrison L.	10.8724	9.9434	9.8321	12.6649	10.6753	10.4302
Jackson L.	0.6716	0.5721	0.5555	0.8304	0.6344	0.6053
Kiser L.	5.9934	5.2698	5.1779	7.2549	5.7601	5.5717
Logan L.	7.1856	5.9613	5.7997	9.2500	6.7512	6.4261
Madison L.	16.7263	14.7369	14.4934	20.4522	16.2523	15.7192
Wolf Run	8.4652	4.4054	3.8095	14.4935	6.5131	5.4114
Limited HP	**6.7645**	**5.6025**	**5.4454**	**8.7071**	**6.3440**	**6.0322**
Buckeye L.	0.2487	0.2368	0.2354	0.2730	0.2465	0.2432
Caesar C.	0.2006	0.1301	0.1204	0.3094	0.1679	0.1492
Grand L. St.	0.0597	0.0534	0.0526	0.0707	0.0575	0.0558
Indian L.	0.1963	0.1754	0.1728	0.2332	0.1891	0.1837
L. Loramie	2.7376	1.2899	1.1079	4.4698	1.9057	1.5823
L. White	8.4366	4.0247	3.4457	16.0764	6.9101	5.6806
Mosquito L.	0.1196	0.0936	0.0902	0.1606	0.1081	0.1014
Rocky Fork	0.5969	0.3318	0.2978	1.0271	0.4831	0.4138
Unlimited HP	**0.3296**	**0.2106**	**0.1956**	**0.5413**	**0.2854**	**0.2531**

(1995) which shows that lobbying of Ohio House representatives by lakeside homeowner's associations is an important factor in obtaining dredging funds from ODNR. Such organizations do not exist at all lakes, and larger lakes, like Indian Lake, have politically active lobby groups which have been successful in obtaining dredging funds. One might argue that lakeside residents who gain benefits from dredging should bear some of the dredging costs by paying higher property taxes or levies. The results of this study also show that implementing upstream soil conservation practices can generate relatively more benefits to downstream lakeside residents in terms of the property rent equivalent than dredging.

Summary and Conclusions

The main objective of this study is to estimate the economic impact of sedimentation on lakeside residential property values at Ohio state park lakes, and provide some economic evidence for an optimal combination of changing upstream soil conservation practices and downstream dredging projects to reduce the sedimentation problem. A Hedonic Price and LA/AIDS model was developed to estimate the impacts of sedimentation on lakeside property values. The important environmental factors that affect property values (in terms of annual rent) are the average depth of the lakes, the rate of sediment entering the lakes as a percent of lake volume, and the amount of sediment annually dredged.

There are four main conclusions that can be drawn from this empirical study. First, on-site factors, such as the average depth of a lake and the amount of sediment dredged annually have positive impacts on lakeside property rent. Lakeside property rents increase at a decreasing rate as lakes become deeper, and increase directly with the amount of sediment dredged. Alternatively, the off-site (upstream) environmental factor, measured by the rate of sediment inflow entering the lakes, has a negative influence on lakeside property rent, meaning higher rates of sediment inflow directly lower the property values. Second, the environmental factors are substitutes for one another. Third, lakeside residents at the limited HP lakes (Harrison Lake, Guilford Lake, Jackson Lake, Kiser Lake, Logan Lake, Madison Lake, and Wolf Run) have more to gain from increases in average lake depth and reductions in sedimentation rates if a dredging project and/or upstream soil erosion control are proposed than do residents at the unlimited HP lakes (Buckeye Lake, Caesar Creek, Grand Lake St Marys, Indian Lake, Lake Loramie, Lake White, Mosquito Lake, and Rocky Fork). Finally, lakeside residents generally have a higher willingness to pay per acre-foot of sediment reduction for upstream soil conservation practices than for lake dredging. This may be in part due to three factors: first, the presence of dredging equipment can be an environmental disamenity in and of itself, second, reduced sediment inflow may be related to reductions in turbidity, and finally, dredging must be repeated continually while upstream conservation practices may have long term implications for reduced sediment inflow.

The foregoing suggests that implementing the upstream soil conservation practices will generally provide more economic benefits to downstream lakeside residents in terms of increasing property rent than increasing average depth of the lakes through dredging. Therefore, targeting soil erosion control based on off-site damages to downstream lakeside property values is likely to result in higher societal benefits. This has important implications for the downsized CRP within the current Farm and Food Bill. Targeting CRP lands based on avoided downstream sediment impacts will be critical. For example, CRP contracts on 21.2 million acres in the U.S. expired on September 30, 1997 and the U.S.D.A. accepted only 11.7 million of those acres into the new program. Another five million new acres were added due to a new set of sign-up criteria where other factors than erosion potential are considered in the decision to retire a parcel of land. It is arguable that such incentive programs may not necessarily be the best incentive mechanisms, and taxes or penalties rather than subsidies could also be considered to optimize net social economic benefits. For example, society might decide to impose penalties based on downstream damage of soil erosion from upstream soil loss above the T-level and subsidize reductions in upstream soil loss below the T-level. This, of course, shifts property rights from upstream to downstream users.

This study focuses on a single category of off-site economic impacts from sedimentation. However, other off-site damages on downstream lakeside residents (such as boater value loss), municipal and industrial users (such as flood control and water treatment costs) should be explicitly incorporated to optimize the full social net benefits from soil conservation. It also would be useful to survey lakeside renters and owners to determine the actual extent to which they are taking depth and sediment inflow into their decision to purchase or rent a given property. Finally, it may be possible to utilize benefit transfer methods to generalize these results from Ohio to other states, particularly in the North Central, North East, and Appalachian regions of the U.S. A current research project at Ohio State University is investigating this potential (Hitzhusen and French, 1998).

References

Bartik, Timothy J. 1988. "Measuring the Benefits of Amenity Improvements in Hedonic Price Models." *Land Economics* 64(2):72–83.

Bartik, Timothy J. 1987. "The Estimation of Demand Parameters in Hedonic Price Model." *Journal of Political-Economy* 95(1):81–88.

Bejranonda, Somskaow. 1996. "An Assessment of the Soil Erosion Impacts on Lakeside Property Values in Ohio: A Hedonic Pricing Method Application." PhD Dissertation. Ohio State University Department of Agricultural Economics, Columbus, OH.

Brown, J.N., and H.S. Rosen. 1982. "On Estimation of Structural Hedonic Price Models." *Econometrica* 50:765–768.

Clark, E.H. II, J.A. Havercamp and W. Chapman. 1985. "Eroding Soils: The Off-Farm Impacts." The Conservation Foundation. Washington, DC.

Deaton, Angus, and John Meullbauer. 1980. "An Almost Ideal Demand System." *American Economic Review* 70(3), 312–326.

Driscoll, Paul, Jeffrey Alwang & Brian Dietz. 1994. "Welfare Analysis When Budget Constraints are Nonlinear: The Case of Flood Hazard Protection." *Journal of Environmental Economics and Management* 26:2:181–199.

Epple, Dennis. 1987. "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products." *Journal of Political-Economy* 95(1):81–88.

Hitzhusen, Fred J. 1991. "The Economics of Sustainable Agriculture: Adding a Downstream Perspective." *Journal of Sustainable Agriculture* 2(2):75–89.

Hitzhusen, Fred J., and Dustin French. 1998–1999. Soil Erosion and Lake Recreation Values: a Benefit Transfer Analysis of Ohio and Adjacent Regions." OARDC Competitive Grant, Ohio State University.

LaFrance, Jeffrey. 1991. "Consumer Surplus vs. Compensating Variation Revisited." *American Journal of Agricultural Economics* 73(5):1496–1507.

Lehman, Timothy S., Fred J. Hitzhusen, and Marvin Batte. 1995. "The Political Economy of Dredging to Offset Sediment Impacts on Water Quality in Ohio's State Park Lakes." *Journal of Soil and Water Conservation* (November–December) 513–516.

Linneman, Peter. 1981. "The Demand for Residence Site Characteristics." *Journal of Urban Economics* 9:129–148.

Macgregor, D.R. 1988. "The Value of Lost Boater Value Use and the Cost of Dredging: Evaluating of Two Aspects of Sedimentation in Ohio's State Park Lakes." Unpublished Ph.D. Dissertation. The Ohio State University.

Macgregor, R., Judith A. Maxwell, and Fred J. Hitzhusen. 1991. "An Operational Model for Targeting Erosion Remediation on the Basis of Partial Off-Site Damage Assessments." *Journal of Soil and Water Conservation* (July–August) 301–304.

Mendelsohn, Robert. 1984. "Estimating the Structural Equations of Implicit Markets and Household Production Functions." *Review of Economics and Statistics*, 673–677.

Nelson, Jon P. 1978. "Residential Choice, Hedonic Prices and the Demand for Urban Air Quality." *Journal of Urban Economics* 5:357–369.

Parsons, George R. 1986. "An Almost Ideal Demand System for Housing Attributes." *Southern Economic Journal* 53:347–363.

Palmquist, Raymond B. 1988. "Welfare Measurements for Environmental Improvements Using the Hedonic Model: the Case of Non-parametic Prices." *Journal of Environmental Economics and Management* 15:297–312.

Palmquist, Raymond B., Fritz M. Roka and Tomislav Vukina 1997. "Hog Operations, Environmental Effects and Residential Property Values." *Land Economics* 73(1):114–124.

Quigley, J.M. 1984. "Non-Linear Budget Constraints and Consumer Demand: An Application to Public Programs for Resident Housing." *Journal of Urban Economics* 12:177–201.

Rosen, Sherwin 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economics* 82:34–55.

The U.S. Soil Conservation Service and the U.S. Forest Service. 1990. "Impact of Nonpoint Pollution on Lakes in Ohio." (August).