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Evaluating the Cost Effectiveness of Land Retirement Programs

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Abstract

This paper extends an integrated framework that combines economic, environmental and GIS modeling to evaluate the cost effectiveness of land retirement programs. The modeling framework is applied to the Lower Sangamon Watershed in Cass County of Illinois to examine the economic costs and environmental benefits of three land retirement scenarios: land actually enrolled in the Illinois CREP, land selected by a land rental cap mechanism and land identified by a least cost model. We find that land retirement in the watershed successfully achieved the program goal of 20% sediment abatement. However, in achieving the same level of sediment abatement, the costs of actual land retirement are 1.3 times and 2.1 times of those in a land rental cap mechanism and a least cost model respectively. The model results also reveal that cost effective land retirement parcels are more sloping, close to river, with higher upland sediment inflow, more on-site erosion and lower quasi-rents. The results indicate that governments may improve the cost effectiveness of land retirement program through targeting. And there is a need to modify current Illinois CREP eligibility criteria to include sloping cropland adjacent to the river in the program. Furthermore our results suggest that in the program implementation land retirement contracts could be selected based on several measurable parameters such as distance from the river and slope.

Key Words: land retirement, cost effectiveness, integrated modeling framework, CREP.

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I. Introduction

As the nation's largest conservation program, the Conservation Reserve Program (CRP) have invested billions of dollars of public funds for encouraging eligible landowners to retire their environmental sensitive land and to plant conservation covers (USDA 2000a, 2000b). Program administrators have gradually modified the rules in order to improve the cost effectiveness of the program. The eligibility criteria of the CRP, for example, has been modified from the erodibility index (EI)[1] to environmental benefit index (EBI)[2] since early 1990s with a focus on off-site water quality and other related environmental benefits (USDA 1997). The Conservation Reserve Enhancement Program (CREP), an addition and modification of current CRP, mostly restricts its program area to environmentally sensitive riparian buffers in river basins of national and regional significance. While these modifications to the CRP have the potential to improve the benefits of the program (Feather *et al*. 1999), how to quantitatively evaluate the cost effectiveness of the land retirement programs is still a research problem that needs to be addressed.

The implementation of land retirement programs like the CRP or CREP is essentially a spatial decision problem because the contracts are approved and installed in specific locations. With detailed spatial data of land retirement contracts gradually available (Illinois Department of Natural Resources 2002), there exists a research need to quantify the costs and benefits of these contracts and therefore, to provide insights for improving the design and implementation of such program in the future. The research problem, however, is complicated because it is almost infeasible to measure the environmental benefits of land retirement through costly monitoring. On one hand monitoring results could not be simply used in determining the environmental benefits achieved by a land retirement program because the benefits may be improved or offset by sources other than the program. On the other hand there exist time lags in linking monitoring results with land retirement actions. As a result, modeling approach becomes a feasible way to address this problem. Nevertheless, the estimation of environmental benefits from the retirement of a land parcel is still complicated because land parcels are interdependent in providing environmental benefits. The water quality benefits of retiring a land parcel, for example, depend on its relative position and landuse decisions of other land parcels in a surface runoff channel. This is the so-called endogenous pollution transport problem (Lintner and Weersink 1999; Yang 2000).

This paper extends an integrated framework of economic, environmental and GIS modeling developed previously to evaluate the cost effectiveness of land retirement contracts in the Illinois CREP (Yang 2000). The Illinois CREP was established in 1998 with environmental goals such as reducing sediment loading by 20% and nitrate loading by 10% in the Illinois River. With about $500 million budget, the program seeks to retire 232,000 acres of cropland, 85% of which are to be selected from riparian areas (defined as the 100-year floodplains of the Illinois River and its tributaries and streams and wetlands). The remaining 15% could be selected from highly erodible cropland adjacent to enrolled riparian areas (USDA 1998). From 2000 the Illinois Department of Natural Resources has started to locate actual CREP contracts in a few key watersheds in the program area with the GPS technology.

The integrated modeling framework is applied to the Lower Sangamon Watershed in Cass County of Illinois to examine the economic costs and environmental benefits of three land retirement scenarios: land actually enrolled in the Illinois CREP, land selected by a land rental cap mechanism and land identified by a least cost model. The land rental cap mechanism selects land with quasi-rents below the cap to achieve specified environmental goals and it resembles the bidding cap system that has been widely applied in land retirement programs. The least cost model identifies land to achieve the specified environmental goals while minimizing costs. This is the cost effective approach of land retirement and it serves as a benchmark in evaluating the cost effectiveness of land retirement programs. The integrated modeling framework accommodates the endogeneity of land parcels in determining off-site pollution abatement benefits. Land and soil characteristics such as slope, distance from rivers, on-site erosion, upland sediment inflow and quasi-rents are also examined to determine their importance in cost effective land retirement. And policy implications of the cost effective land retirement are discussed.

Several literatures studied cost effectiveness of conservation programs. Smith (1995) applied the mechanism design theory to study the properties of a least cost Conservation Reserve Program (CRP). However, his focus is on the costs for achieving specified acreage goal, without the consideration of environmental benefits. Shakya and Hitzhusen (1997) revealed that tree planting is a viable option for some CRP land in the Midwest through benefit cost analyses. Babcock *et al*. (1996, 1997) analyzed the variations in the joint spatial distribution of CRP costs and environmental benefits and argued that targeting CRP land based on either minimizing costs or maximizing benefits may cause efficiency losses compared with targeting criteria based on benefit to cost ratio. Ribaudo (1986, 1989) analyzed the costs of regional or watershed level targeting of CRP using both on-site and off-site environmental benefits. He found that ignoring off-site benefits leads to inefficient resource allocation because of the large differences in the ratio of off-site to on-site benefits. These studies revealed the importance of jointly considering economic costs and off-site environmental benefits in targeting or evaluating land retirement programs. However, these studies focus on analyzing conservation programs at national or large regional level and have relied on highly aggregated data or crude index measures in estimating environmental benefits. As a result, their methodologies are not readily applicable in evaluating the cost effectiveness of land retirements at watershed scale.

One of the difficulties in evaluating the cost effectiveness of conservation programs is to address the endogeneity of land parcels in determining off-site environmental benefits. Some studies focusing on a social planner's strategies for reducing off-site pollution damages, assumed exogenous or partially endogenous pollution transport process based on site-specific factors only (Carpentier *et al*. 1998) or site-specific characteristics of downslope parcels (Braden *et al*. 1989). Lintner and Weersink (1999) have addressed the interdependence of pollution transport process in analyzing sediment-bound pollution control policies. However, their assumption of identical land parcels reduced the true complexity of the endogeneity problem. The integrated framework developed Yang (2000) fully accounted the interdependence and heterogeneity of land parcels in provided off-site sediment abatement benefits to examine the targeting of cost effective land retirement in Illinois.

Comparing with previous research this paper advances knowledge in empirically quantifying the cost effectiveness of actual contracts in land retirement programs, with explicitly accounting of the spatial dimension. The insights provided by the empirical results have important implications for the design and implementation of land retirement programs. Furthermore, the methodology developed in the study is also applicable in evaluating the cost effectiveness of other conservation programs.

II. Empirical Modeling Framework

This study extends an integrated framework developed by Yang (2000) to evaluate the economic costs and environmental benefits of three land retirement scenarios: land actually enrolled in the Illinois CREP, land selected by a land rental cap mechanism and land identified by a least cost model. For simplicity and being consistent with the primary goal of the Illinois CREP, the integrated modeling framework only considers sediment abatement as the environmental benefits of land retirement programs. And landowners are assumed only having two decision choices: cropping or retirement of land. In the integrated modeling framework, a crop budget model is used to estimate quasi-rents of cropland (FaRM laboratory 1995). The forgone quasi-rents represent the economic costs of land retirement. The Agricultural Non-point Source Pollution (AGNPS) model, a widely applied hydrologic model (Young *et al*. 1994, 1995), is used to estimate off-site sediment abatement benefits from land retirement. The Geographic Information System (GIS), on the other hand, provides a framework to integrate economic and environmental data with common spatial references.

We first partition an agricultural watershed into standard-sized land parcels in GIS and establish a grid structure for the watershed. In this study, a parcel size of 300-by-300 foot (2.07 acres per parcel) is chosen because it leads to land parcels that are relatively homogeneous in their soil characteristics and slope. Data could also be easily obtained from GIS data sources and matched to this parcel size. In addition, actual land retirement contract data in the Illinois CREP shows that the size of the smallest land parcels enrolled in the program was between 1 and 2 acres and suggests that the chosen parcel size is reasonable.

Standard-sized land parcels are then grouped into runoff channels or flow paths for sediment flow from upland areas to the river based on surface hydrology (Yang 2000). The purpose of grouping land parcels into surface runoff channels is for accommodating the endogeneity of land parcels in proving off-site sediment abatement benefits, which will be elaborated later. When the empirical framework is applied to examine the two simulated land retirement scenarios based on a land rental cap mechanism and a least cost model, we only consider cropland within a 900-foot buffer (the length of the first three parcels) along all streams and tributaries to be eligible for the program. The rationale is that the buffer area encompasses most of the 100-year floodplains along the streams, which is defined as the eligible area for CREP enrollment in Illinois. Furthermore, the buffer width is sufficient for meeting the needs of many wildlife species (USDA 1996). The actual land retirement contracts may be located beyond the 900-foot buffer region because of relaxation in program implementation. However, as it will be verified in empirical applications, majority of actual land retirement contracts were within 900-foot buffer and they contributed most of the off-site sediment abatement benefits. The definition of 900-foot buffer as eligibility region in the simulation models should lead to consistent comparison of the three land retirement scenarios for evaluating the cost effectiveness of land retirement programs.

After the spatial configuration of the watershed is set up we estimate the quasi-rents of crop production based on soil types. The quasi-rents are defined as total revenues minus total variable costs in crop production, where the variable cost items include seeds, fertilizers, pesticides, herbicides, machinery use and labor, crop insurance and interest. The quasi-rent estimation is based on a 700-acre farm, the average-sized commercial operation in central Illinois, growing corn and soybean using reduced-till system[3] (Yang 2000). However, the quasi-rents vary across land parcels because crop yields and inputs change according to each parcel's soil productivity rating. Soil productivity information in Olson *et al*. (1999) is used to determine maximum potential crop yields. These expected yield estimates are used together with recommended input-output ratios based on the Illinois Agronomy Handbook (Cooperative Extension Service 1999) to determine the quantities of variable inputs include seeds, fertilizers, pesticides and herbicides. The variable costs of machinery and labor required for a 700 acre corn and soybean farming operation are calculated by using a machinery program developed by Siemens (1998). We collected data on output and input prices for 1998 from various state sources (Illinois Farm Business Farm Management Association 1999; Pike 1999). All of the above data are entered into a crop budget model (FaRM Laboratory, 1995) to estimate quasi-rents per acre by soil types with the adjustment of slopes. The overlay of soil-based quasi-rent data with the watershed grid in GIS assigns the quasi-rent data to cropland parcels.

A GIS interface is adapted to prepare input data for the AGNPS model (Liao 1997). The AGNPS model run needs input data for 5 parameters at watershed level and 23 parameters at parcel level (Young *et al*. 1994; 1995). The justifications of the key parameters are as follows: Rainfall data from the Illinois State Survey (Huff and Angle 1989) are used to construct a typical 5-year storm event (3.73 inches of rainfall for 12 hours) and calculate rainfall energy intensity value. The elevation data (U.S. Geological Survey 1997) are used to determine surface runoff direction (aspect) and slope for every parcel. Slope-based slope length data are provided by local Natural Resources Conservation Services in Illinois. The soil texture and soil erodibility are extracted from soil data (Illinois Natural Resources Conservation Services 1996). Soil hydrologic group data and land use data (Illinois Department of Natural Resources 1996) are jointly used to determine runoff curve numbers (USDA 1972; 1986). Land use data also provide a basis for determining Manning's roughness coefficient, surface condition coefficient, cropping management factor, conservation practice factor and chemical oxygen factor (Young *et al.* 1994; Wischmeier and Smith 1978; Walker and Pope 1983). Other parameters are based on AGNPS defaults. And all the input parameters are adjusted in consultation with Illinois Natural Resources Services officials and hydrologists to fit into conditions in the model application area.

The empirical modeling framework is applied to examine the economic costs and sediment abatement benefits in actual land retirement scenario. We convert the actual land retirement contracts into standard sized parcels. The overlay of soil-based quasi-rent data with the watershed grid assigns quasi-rents to these land parcels. Then the hydrologic model AGNPS is run to estimate off-site sediment loading with actual land retirement contracts. Because of the endogenous pollution transport process we estimate off-site pollution abatement jointly achieved by retired land parcels within the same runoff channel, instead of individual land parcels, through the comparison of sediment loading in the base scenario without land retirement and in actual land retirement scenario. From above steps we obtain the costs and benefits of actual land retirement contracts in the watershed.

When applying the empirical framework to examine the other two simulated land retirement scenarios we need to estimate off-site sediment abatement benefits from all eligible land parcels and to select land parcels based either on a land rental cap mechanism or a least cost model . The complication of the estimation is that land parcels are interdependent in determining off-site sediment abatement benefits. We develop an innovative land retirement scheme to overcome this complication. We consider every three-parcel chain in a runoff channel as a decision-making unit, instead of individual parcels. For each three-parcel chain, we define $p = 8$ (2^3) alternative land retirement plans that represent all possible combinations of discrete land retirement decisions (retire/continue cropping) for the three parcels that make up the chain. These combinations are *GGG*, *GGC*, *GCG*, *GCC*, *CGG*, *CCG*, *CGC*, and *CCC* where *C* denotes crop production and *G* denotes enrollment in a land retirement program that requires the planting of permanent grass cover. Land retirement plan *CCC* is the base scenario without land retirement and is denoted as $p = 1$.The AGNPS model is run for the entire watershed with each of the eight land retirement plans to estimate off-site sediment loadings of surface runoff channels, denoted as e_{pj} for surface channel j with land retirement plan p. Comparing with sediment loadings in the base scenario we obtain the estimates of sediment abatement benefits achieved by surface runoff channel j under land retirement plan p, that is $(e_{1j} - e_{pj})$. For each land retirement scenario we also obtain relevant quasi-rent losses, denoted as $(r_{1j} - r_{pj})$.

In the land retirement scenario based on a rental cap mechanism, land parcels with quasi-rents below the cap are selected for retirement. The rental cap is determined such that specified off-site sediment goal is achieved. This land retirement scenario resembles the bidding cap system that has been widely applied in land retirement programs like the CRP. When the rental cap is applied to the eligible land parcels in the watershed, land retirement in a three-parcel chain must fall in one of the eight possible land retirement plans. A heuristic procedure is developed to summarize the quasi-rent losses, $(r_{1j} - r_{pj})$, and off-site sediment abatement, $(e_{1j} - e_{pj})$, for all three-parcel chains with at least one retired land parcel. We start from a low rental cap and then systematically raise the value in small increments until the specified sediment abatement goal in the watershed is achieved. From the procedure we obtain a land rental cap, a land retirement pattern, and associated quasi-rent losses and off-site sediment abatement benefits.

In the land retirement scenario based on a least cost model, land parcels are selected to achieve specified off-site sediment abatement goal while minimizing quasi-rent losses. This is the cost effective land retirement scenario. The land retirement pattern in this scenario is identified through an optimization model. The decision problem is to choose land retirement plan p in flow chain j to minimize forgone quasi-rents and achieve specified sediment abatement goal. Typically this type of problem is formulated as an integer programming model. However, for an average watershed, this model involves a large number of parcels and even more land retirement plans. This would lead to a large-scale integer programming that would be computationally complex. To cope with the complexity we develop a linear program approximation that transfers the complex model into a computationally convenient model.

To choose among the eight alternative land retirement plans for each chain we introduce an endogenous convex combination (weight) variable associated with land retirement plan p for channel j, denoted by Z_{pj} where $0 \le Z_{pj} \le 1$ with $\sum_{p=1}^{8} Z_{pj} = 1$ for all j. Suppose that the sediment abatement objective for the entire watershed is specified and denoted by $\overline{A}$. The algebraic model that determines the least cost land retirement scenario for the J channels in a watershed is:

(1) Min $\sum_{j=1}^{J} \sum_{p=1}^{8} (r_{1j} - r_{pj}) Z_{pj}$

Subject to:

(2) $\sum_{j=1}^{J} \sum_{p=1}^{P} (e_{1j} - e_{pj}) Z_{pj} \ge \overline{A}$

(3) $\sum_{p=1}^{8} Z_{pj} = 1$ for all $j = 1, \ldots J$

(4) $Z_{pj} \ge 0$ for all p, j

Note that in the above formulation the endogenous weight variables, Z_{pj}, are defined as continuous variables, rather than binary variables. Therefore, equations (1) through (4) define a linear programming model. It could be shown[4] that in any optimal solution, all Z_{pj} except one pair of variables defined for a single channel j, have to take binary values, namely either *0* or *1*. And after rounding the non-binary solution for that single channel to a binary solution, we obtain a pure binary optimal solution that very closely approximates the true binary solution of the land retirement problem that would be obtained from an integer programming formulation (where Z_{pj}'s would be defined as binary variables). The optimization model provides a least cost land retirement pattern, and associated quasi-rent losses and off-site sediment abatement benefits.

III. Data Description

The integrated modeling framework is applied to an agricultural watershed, Lower Sangamon Watershed, in Cass County of Illinois. The Lower Sangamon Watershed has 129,506 acres and is composed of four USGS 13-digit watersheds[5]: Shadd Ditch watershed, Jobs Creek watershed, Panther Creek watershed and Middle Creek watershed. The landuse structure is cropland 58.1%, grassland 17.6%, woodland 18.7%, wetland 4.3% and other 1.3%. The slope structure is 0-2% slope, 54.5%; 2-5% slope, 19.2%; 5-10% slope, 13.4% and greater than 10% slope, 12.9%. So this watershed is primarily agricultural and relative flat in landscape, which is typical of Illinois conditions.

We partition the watershed into 300-by-300 foot parcels (2.07 acres per parcel), resulting in 61,790 parcels. Of the runoff channels that cover the watershed, 6,360 runoff channels contain cropland parcels within 900-foot buffer of rivers in the watershed. Without counting non-cropland parcels in the runoff channels, 13,484 parcels (27,912 acres) of cropland are eligible for land retirement. These cropland parcels amount to 21.8% of the watershed area and 37.1% of the total cropland in the watershed.

Summary statistics for the eligible cropland parcels in the watershed are provided in Table 1. Land parcels differ considerably in their distance from river, slopes, erodibility index, upland sediment inflow, on-site erosion and quasi-rents per acre. The distance from river reflects the positions of all eligible land parcels within a watershed (the first parcel adjacent to river, 150 feet; the second parcel, 450 feet; the third parcel, 750 feet). The eligible land parcels have an average distance from river 397.9 feet, which is in the range of the second parcel. This indicates that the eligible land parcels are relatively evenly distributed in position 1, 2 and 3. Slopes range between 0.5% and 15% with an average of 1.8%. The average erodibility index is 0.32. The upland sediment inflow per acre ranges from 0.0 tons to 57.2 tons with an average of 2.0 tons.

The on-site erosion per acre ranges from 0.8 tons to 53.6 tons with an average of 5.2 tons. And the quasi-rent per acre ranges from $67.0 to $204.9 with an average of $175.2.

Relevant data are also obtained for actual CREP land retirement contracts in the watershed since March 1998 through July 2001. There are 6,625.7 acres of land retirement in the watershed. The GIS conversion leads to 3,201 standard-sized land retirement parcels. Quasi-rent data are estimated for these land parcels. The AGNPS model is also run for the actual land retirement pattern and corresponding off-site sediment abatement is estimated. The summary statistics for actual land retirement pattern in the watershed are listed in Table 3. The description of the summary statistics is postponed to next section when comparing with the other two simulated land retirement scenarios.

IV. Empirical Results

The empirical modeling framework is applied to the Lower Sangamon Watershed firstly to examine the costs and benefits of actual land retirement contracts in the Illinois CREP. The model results are shown in Table 2. In the base scenario, which defines as the situation with no land retirement, the off-site sediment loading to the river under a typical 5-year storm event (3.73 inches in 12 hours) is 38,720.2 tons. In the watershed 6,625.7 acres of cropland are enrolled in the Illinois CREP since March 1998 through July 200. The corresponding quasi-rent losses are $1,005,933.3. This represents 8.8% of all cropland and 23.7% of eligible cropland in the watershed. The estimated sediment loading after the land retirement is 29,230.8 tons. This indicates 24.5% of off-site sediment abatement. Considering the Illinois CREP goal of 20% sediment abatement, land retirement in the watershed is quite successful in achieving the program goal.

The integrated modeling framework is then applied to identify land retirement patterns based a land rental cap mechanism and a least cost model. In order to consistently compare the two simulated land retirement scenarios with the actual land retirement scenario we set the off-site sediment abatement constraint to 24.5%, which is the sediment abatement goal achieved by the actual CREP contracts. We find that 5,493.8 acres and 3295.4 acres of land are selected for retirement in a land rental cap mechanism and a least cost model respectively, in order to achieve the sediment abatement goal under a 5-year storm event (abatement of 9,489.4 tons of sediment loading). In the land rental cap scenario, the retired acreage is 7.3% of all cropland and 19.7% of eligible cropland in the watershed. In the least cost scenario, the retired acreage is 4.4% of all cropland and 11.8% of eligible cropland in the watershed. The costs of the 24.5% sediment abatement are measured by the forgone quasi-rents on the retired land parcels, which also represent the minimum payment the landowners would be willing to accept to retire their land from crop production. The forgone quasi-rents are $757,840.0 and $486,895.1 for the land rental cap scenario and the least cost scenario respectively. The results from actual land retirement scenario and the two simulated land retirement scenarios are quite contrasting. In achieving the same level of sediment abatement, the acreage and quasi-rent losses of actual CREP contract are 1.2 and 1.3 times of those in a land rental cap scenario, 2.0 and 2.1 times of those in a least cost scenario respectively. The results reveal that there is much potential for the current Illinois CREP to improve its cost effectiveness.

In order to provide insights in the factors that cause the differences in the costs and benefits of the three land retirement scenarios in the watershed, summary statistics for distance from river, slope, erodibility index, upland sediment inflow, on-site erosion, and quasi-rents for the three scenarios are generated (see Table 3). We also find very contrasting results from the comparison. The distances of actual land retirement parcels from river are between 150 to 8,550 feet. As defined, the selected land parcels in the two simulated land retirement scenarios are with distance from river between 150 to 750 feet. The actual land retirement parcels have an average distance from river 971.8 feet. In contrast, the land rental cap scenario and least cost scenario have average distances from river 410.0 feet and 267.4 feet respectively. For more consistent comparison of the three land retirement scenarios we identified actual land retirement within 900-foot buffer. There are 2,097 land parcels or 4,340.8 acres of land within 900-foot distance of the river, which represents 65.5% of total land retirement acreage. We run the hydrologic model AGNPS and find that the actual land retirement within 900-foot buffer contributes off-site sediment abatement 8580.6 tons, which represent 90.4% of total sediment abatement achieved by all land retirement contracts. Interestingly, the actual land retirement within 900-foot buffer achieved 22.2% sediment abatement over the base loading, which already exceeds the program goal of 20% sediment abatement. This indicates that the actual land retirement contracts located beyond 900-foot buffer are not important in contributing to the program goal. And it shows that the distance from river plays an important role in determining the off-site sediment benefits of retired land parcels.

The average values of other sediment abatement related variables for actual land retirement parcels are slope 3.9%, erodibility index 0.33, upland sediment inflow 3.1 tons per acre, on-site erosion 12.1 tons per acre. In the land rental cap scenario, the retired land parcels have average slope 4.8%, erodibility index 0.4, upland sediment inflow 3.5 tons per acre, on-site erosion 12.9 tons per acre. For selected land parcels in the least cost scenario the corresponding average values are slope 6.5%, erodibility index 0.4, upland sediment inflow 4.8 tons per acre and on-site erosion 17.3 tons per acre. Apparently retired land parcels in the two simulated land retirement scenarios have higher on-site erosion potential and more upland sediment inflow. As a result the retirement of these land parcels lead to higher off-site sediment abatement. The contrast between the actual land retirement scenario and the least cost scenario is more significant that the contrast between the actual land retirement scenario and the land rental cap scenario.

In another end, the average quasi-rent per acre in the land rental cap scenario is less than that in the actual land retirement scenario. This is because the land rental cap scenario only selects land parcels with lower quasi-rents. The retired land parcels in the least cost scenario on average are also less costly than actual land retirement parcels. The average quasi-rent per acre is $145.6 in the least cost scenario and $151.8 in actual land retirement scenario. However the gap between average quasi-rents in the two land retirement scenarios is not much. This may be caused by the fact that cropland parcels in the watershed are highly productive on average.

In summary, we find that the selected land parcels in the two simulated land retirement scenarios, especially in the least cost scenario, are more sloping, close to river, with higher upland sediment inflow and on-site erosion, comparing with the actual land retirement scenario. Furthermore, the selected land parcels in the two simulated scenarios are with lower quasi-rents, which is consistent with a cost effective policy. The results show that slope, upland sediment inflow and on-site erosion are positively related and distance from river is negatively related with off-site sediment abatement. This indicates that although the off-site sediment abatement by a land parcel depends considerably on its on-site erosion levels, it also depends on the location of the land parcel. The parcels close to the river have the benefits of depositing sediment inflow from upland and do not have too many downslope parcels on which to deposit their sediment. Hence, selection of land parcels with higher on-site erosion and upland sediment inflow that are close to the river is cost effective since it would have a substantial impact on reducing sediment loading in a river. Among the parcels with higher contribution to off-site sediment abatement, cost effective targeting chooses those parcels with the lowest forgone quasi-rents. As a result, the quasi-rents of selected parcels in the two simulated scenarios are lower than those in the actual land retirement scenario.

V. Conclusion

Since conservation provision of the 1985 Food Security Act land retirement programs have become important public initiatives in reducing environmental damages caused by agricultural activities in the United States. With huge government investment in these programs, how to quantify the cost effectiveness of these programs is a research question of theoretical and practical significance. This study extends an integrated framework that combines economic, environmental and GIS modeling to evaluate the cost effectiveness of actual land retirement programs.

The integrated framework is empirically applied to the Lower Sangamon Watershed in Cass county of Illinois. We find that actual land retirement of the Illinois CREP in the watershed is successful in achieving the program goal of sediment abatement. However, the actual land retirement contracts are much more costly than the two simulated land retirement scenarios. In achieving the same level of sediment abatement, the acreage and quasi-rent losses of actual CREP contract are 1.2 and 1.3 times of those in an easily implemented land rental cap scenario. The acreage and quasi-rent losses of actual CREP contract are 2.0 and 2.1 times of those in a least cost scenario, which is the benchmark of cost effective land retirement. The model results also revealed following attributes of cost effective land retirement parcels: more sloping, close to river, with higher upland sediment inflow and more on-site erosion. Furthermore, the cost effective land retirement parcels are with lower quasi-rents.

Our model results could lead to several important policy implications. First, the government may improve the cost effectiveness of land retirement through targeting. While the least cost scenario is difficult to implement, we have shown that an easily implemented land rental cap mechanism in the buffer region is more cost effective than the actual land retirement scenario. Our results also show that actual land retirement within 900-foot buffer is sufficient for achieving the program goal. Second, modifications in certain program criteria are also desirable. For example, current Illinois CREP defines the majority of eligible land as floodplains, which is flat in nature. The model results indicate that sloping land are contributing more to sediment abatement. So it is reasonable to modify the eligibility criteria to include all cropland in riparian buffer as eligible land. Third, land retirement contracts could be selected based on several measurable parameters such as distance from river and slope. Other factors such as the potential of upland sediment flow and on-site erosion could also be used as supplementary criteria in the selection. We expect these program modifications have the potential to significantly contribute to the cost effectiveness of land retirement programs.

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[1] . Erodibility Index (EI) is defined as the ratio of maximum soil loss and soil tolerance level.

[2] . Environmental Benefit Index (EB)) is composed of six environmental factors: wildlife factor, water quality factor, erosion factor, enduring benefits factor, air quality factor and State or National Conservation Priority Area (CPA) factor.

[3] Reduced-till has less intensive operations on soil than conventional tillage such as smaller cultivation equipment.

[4] . Proof of this needs to use linear programming theory and is available upon request.

[5] . In the United States, watersheds are delineated by USGS using a nationwide system based on surface hydrologic features. The hierarchical system is composed of region (2-digit), subregion (4-digit), accounting unit (6 digit) and cataloguing unit (8 digit). Under cataloguing unit 11-digit watersheds are delineated based on identifiable hydrologic features on the 1:24,000 scale base map. The 13-digit watersheds are further delineated sub-watersheds under 11-digit watersheds. For more details, see http://www.ftw.nrcs.usda.gov/HUC/ni170304.html.

Table 1 Summary Statistics of Eligible Land in the Lower Sangamon Watershed

Variables	Mean(Std.Dev)	Min.	Max
Distance from river (Feet)	397.9 (238.2)	150.0	750.0
Slope (%)	1.8 (2.3)	0.5	15
Erodibility Index	0.32 (0.03)	0.11	0.37
Upland sediment inflow (Tons/Acre)	2.0 (3.3)	0.0	57.2
On-Site Erosion (Tons/Acre)	5.2(5.9)	0.8	53.6
Quasi-rent ($/Acre)	175.2(24.4)	67.0	204.9
Total no. of eligible land parcels	13,484		
Eligible acres	27,911.9		
Total Quasi-rents ($)	4,890,188.1		
Total sediment loading with 5 year storm events(Tons)	38,720.2		

Table 2. Comparison of Actual and Simulated CREP Programs in the Lower Sangamon Watershed

	Base Scenario	Actual CREP Contracts	Actual CREP Contracts within 900-foot Buffer	CREP Targeting Based on a Rental Cap Mechanism	CREP Targeting Based on a Least Cost Model
Land Retirement (Acres)	--	6,626.1	4,340.8	5,493.8	3,295.4
Quasi-rent Losses ($)	--	1,005,933.3	678,630.4	757,840.0	486,895.1
Sediment Loading (Tons)	38,720.2	29,230.8	30139.6	29,230.8	29,230.8

Table 3. Summary Statistics of Actual CREP Sign-up Land Parcels and Cost Effectively Targeted Land Parcels in the Lower Sangamon Watershed with Sediment Abatement 24.5%

Variables	Actual CREP Signups			CREP Targeting Based on $/acre Instrument			CREP Targeting Based on $/ton Instrument		
	Mean (Standard Deviation)	Min.	Max.	Mean (Standard Deviation)	Min.	Max.	Mean (Standard Deviation)	Min.	Max.
Distance from river (Feet)	971.8 (1,233.1)	150.0	8550.0	410.0 (239.8)	150	750	267.4 (189.6)	150	750
Slope (%)	3.9 (4.5)	0.5	15.0	4.8 (3.3)	0.5	15.0	6.5 (3.2)	0.5	15.0
Erodibility Index	0.33 (0.05)	0.01	0.37	0.4 (0.01)	0.11	0.37	0.4 (0.01)	0.16	0.37
Upland Sediment Inflow (Tons/Acre)	3.1 (6.5)	0.0	98.0	3.5 (5.4)	0.0	57.2	4.8 (6.6)	0.0	57.2
On-Site Erosion (Tons/Acre)	12.1 (15.4)	0.01	144.3	12.9 (9.2)	0.8	53.6	17.3 (9.3)	1.6	53.6
Quasi-rent ($/acre)	151.8 (30.4)	56.5	204.9	138.5 (7.0)	67.0	148.1	147.7 (20.7)	67.0	204.9
Total No. of Parcels	3,201			2,654			1,592		

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