Estimating the Long-Term Benefits and Costs of BMPs in an Agricultural Watershed

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This is not a peer-reviewed article.

Paper No: 042174
An ASAE Meeting Presentation

Written for presentation at the

2004 ASAE/CSAE Annual International Meeting
Sponsored by ASAE/CSAE
Fairmont Chateau Laurier, The Westin, Government Centre
Ottawa, Ontario, Canada
1 - 4 August 2004

Abstract. Federal conservation agencies are recognizing the need to account for the millions of dollars spent nation-wide on conservation programs focused on implementing best management practices (BMPs), some of which have been in existence for decades. A cost-benefit analysis for many of these programs is difficult due to the limited water quality and cost data available, and because attempts to quantify the water quality benefits obtained from BMP implementation is problematic. A cost-benefit analysis was performed on a large watershed management project that installed hundreds of BMPs in the mid-1970s, the Black Creek Project. Water quality improvement for sediment and total phosphorus reduction due to BMP implementation was estimated in 2000 dollars using off-site benefit estimates, fertilizer nutrient costs and water quality trading values. The benefits received from the BMPs did not outweigh the costs for implementing and maintaining the BMPs. Benefits not captured in this economic analysis include lessons learned and used outside the watershed by the conservation community, gully erosion, erosion deposited within the watershed, nitrogen reduction, wildlife habitat improvement, human and aquatic ecosystem health, aesthetics, downstream impacts, intangible impacts and the needs of future generations. This study shows that the tools needed to compute an accurate comparison of benefits and costs concerning water quality are lacking. Economic analysis of conservation planning should continue, but should not be the sole determining factor when deciding if a conservation project is worthwhile.

Keywords. Best management practices, cost-benefit analysis, economic analysis, water quality, long-term costs, Soil and Water Assessment Tool

Introduction

Indiana has just over 15-million acres of farmland (USDA, 2002). Any fraction of this farmland transformed from crop or livestock production to space for best management practices (BMPs) can have a financial impact on Indiana's agricultural community, for both the private and public sector. If farmers and policymakers can understand the financial benefits, in addition to the environmental benefits, these practices produce over time, they may be more willing to implement such practices.

Multiple economic analyses to quantify the benefits and costs of improving water quality have been undertaken (Carson and Mitchell, 1993; Doering et al., 1999; Walker and Joehn, 1990; Aust et al., 1996; Yadav and Wall, 1998; Isaac, 1998; Rein, 1999). While economists and conservationists agree that water quality should be monetized, there are concerns from both parties about the way in which dollar values are assigned to water quality improvement, especially to the benefits occurring from reductions in non-point source pollution. Studies that do capture the monetary value of water quality improvement are situation specific and involve numerous assumptions that may not be transferable to other locations. Water is generally a non-market good and natural resources economists are just beginning to deduce the steps needed to undertake the monumental task of assigning a dollar value to water quality for both on-site and off-site purposes.

Cost-benefit analysis (CBA) is the identification, economic valuation, and quantitative comparison of the advantages and disadvantages of public policies based on their net contribution to society's overall well being (Kalman et al., 2000). An *ex post* CBA is conducted at the end of a project and contributes to learning by policymakers and researchers if a particular project is worthwhile from an economic perspective (Boardman et al., 2001). According to Newsome and Stephen (1999), the basic steps to complete a CBA for the purposes of water quality is to first establish the scope of the study by setting any limits, state the benefits that occur from water quality improvement, assign a monetary value to the benefits, calculate the present value of the costs and benefits, and compare or appraise the benefits versus costs.

This paper discusses the process taken to conduct an economic analysis for four structural BMP types implemented during a large watershed demonstration project that ended some 20 years ago and identifies some of the limitations when performing such a benefit-cost analysis. The Black

Creek Project (1973-1984) was a large water quality demonstration project funded by the U.S. EPA that centered on reducing phosphorus and sediment entering the Maumee River (Lake and Morrison, 1977). A plethora of information regarding the land treatment, water quality sampling, and monies spent is available in numerous EPA published reports (Lake and Morrison, 1977; Morrison and Lake, 1983; Lake 1975; Lake and Morrison, 1976). The overall objective of this paper is to provide the benefits and costs associated with the long-term water quality impact of BMPs in good condition.

Benefits of Improved Water Quality

The most challenging part of performing a CBA for water quality is the quantification and estimation of perceived benefits from improved water quality (Newsome and Stephen, 1999; Kalman et al., 2000). It is extremely difficult to assign monetary values to water quality, and to establish monetary values that can be applied to various situations. Because water quality is not a market good, its demand cannot be estimated by directly observing transactions for this good. Furthermore, the CBA process is complicated when accounting for the inclusion of several BMPs that play a role in the amount of water quality improvement (Yuan et al., 2002). The installation of BMPs may produce on-site benefits, those benefits that "occur at or close to the location of the conservation activity, and generally are directly beneficial to the user and/or owner of the resource where the conservation activity was undertaken". By contrast, off-site benefits are those benefits that "occur in different locations than that of the conservation activity and may occur to different resource users and/or general owners and to the general public" (USDA NRCS, 2004).

Materials and Methods

Study Site

The Black Creek watershed, about 5,000 hectares in size, is located in northeast Allen County, Indiana approximately 24 kilometers northeast of the city of Fort Wayne (Figure 1). The watershed is predominantly rural with one small town, Harlan. The watershed drains into the Maumee River, which flows northeast from Fort Wayne to Lake Erie, in Toledo, Ohio. In general, the soils are deep, ranging from moderately well drained to very poorly drained and medium to fine textured. The watershed consists of mostly gently sloping land with an elevation of 256m in the north and 228m at the outlet. Row crop agriculture and pasture make up the primary agricultural land uses. Soybeans and corn are the main crops, followed by winter wheat and other small grains (USDA-NRCS, 2003). There is a significant presence of Amish farmers in the watershed (Morrison and Lake, 1983). Two drainage areas, the Dreisbach and Smith-Fry watersheds were monitored for water quality during the Black Creek Project. For the economic analysis, sediment and erosion reduction were predicted for the BMPs implemented in the Smith-Fry watershed using the Soil and Water Assessment Tool (SWAT).

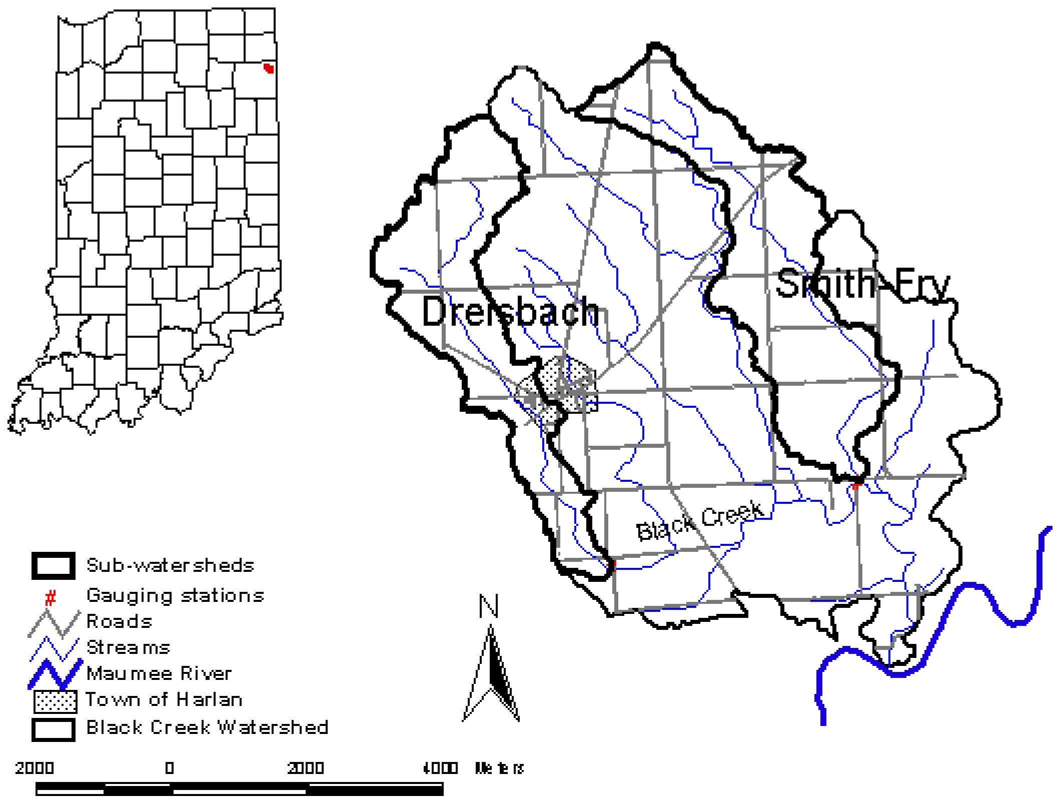

Figure 1 Black Creek watershed location map

Scope of Cost-Benefit Analysis

More than 30 BMP types, structural and non-structural, totaling hundreds of BMPs were implemented during the Black Creek Project (Lake and Morrison, 1977). This cost benefit analysis was performed solely for the grassed waterways, grade stabilization structures, field borders and parallel terraces implemented in the Smith-Fry sub-watersheds. Only benefits occurring as a result of sediment from non-gully erosion and phosphorus reduction, as predicted from the Soil and Water Assessment Tool (SWAT), were tabulated. Other significant benefits, such as gully erosion reduction, wildlife habitat improvement and land productivity, were beyond the scope of this study. Because exact installation dates for many of the BMPs are not known, it was assumed that all BMPs were installed by 1980. The cost benefit analysis was performed for 1980 to 2000. The prediction of sediment and nutrient reduction from SWAT was based on the assumption that the 1975 land use applied stayed constant throughout the 20 years period of analysis.

Calculation Constants

The U.S Department of Labor Bureau of Labor Statistics Producer Price Index-Commodities (finished goods less food and energy) was used to forecast prices from 1980-2000 dollars (Table 1) (US DOL, 2004). An interest rate of 6.5% was used in all future value computations, as this is the same interest rate used by the U.S. Treasury assigned to series E bonds issued in 1970.

Table 1 U.S. Department of Labor Producer Price Index

Year	Annual Index	Year	Annual Index	Year	Annual Index
1980	87.1	1988	117.0	1996	142.0
1981	94.6	1989	122.1	1997	142.4
1982	100.0	1990	126.6	1998	143.7
1983	103.0	1991	131.1	1999	146.1
1984	105.5	1992	134.2	2000	148.0
1985	108.1	1993	135.8	2001	150.0
1986	110.6	1994	137.1	2002	150.2
1987	113.3	1995	140.0	2003	151.0

Benefits of Water Quality Improvement

Benefits received from the installation of the four BMP types were estimated based on predicted sediment and phosphorus reduction. The Soil and Water Assessment Tool (SWAT) was utilized to predict the amount of sediment and total phosphorus (P) reduction. On-site benefits include saving fertile topsoil, fewer eroded stream bank repairs, less tile damage and maximization of crop fertilizer efficiency. Off-site benefits include, but are not limited to, spending less money on water storage, navigation, flooding, clearing roadside and irrigation ditches, and municipal water treatment.

Best management practices in varying conditions – good, fair and poor - were simulated to represent the reduction of sediment occurring from non-gully erosion in SWAT, after model calibration and validation. The Smith-Fry watershed has 1 grassed waterway, 4 grade stabilization structures, 3 field borders and 2 parallel terraces (figure 2). The BMPs were represented in SWAT by modifying parameters that reflect the impact the practice has on the water processes occurring in the model based on the primary functions of the BMP (Bracmort, 2004). Model runs were performed with the inclusion of the BMPs. Assuming landowners maintain the upkeep of their practices, BMPs reduce the sediment and total P yields whether in good or varying condition. BMPs in good condition reduce sediment and total P more than BMPs in varying condition.

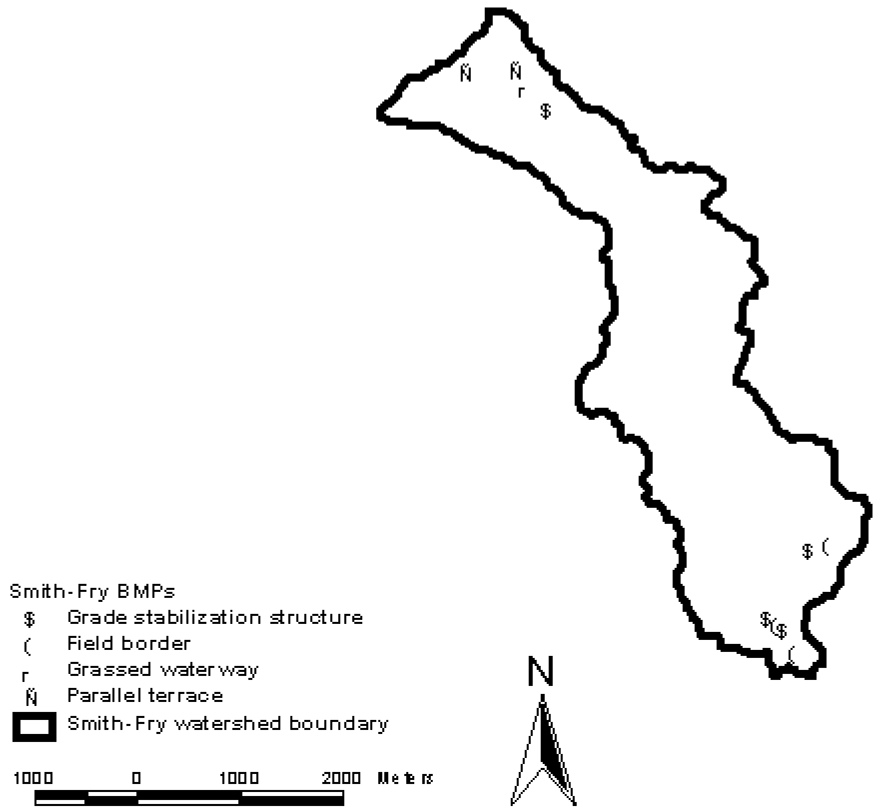

Figure 2 Location of BMPs in the Smith-Fry watershed

Monetary Value of Water Quality Improvement Benefits

The next step was to place a monetary value on sediment and nutrient reduction. Benefits for reducing soil erosion were estimated from Ribaudo et al. (1989) who set the benefit of reducing soil loss equal to the off-site damage of a ton of eroded soil. The damage per ton of erosion was estimated for the following damage categories: freshwater recreation, marine recreation, water storage, navigation, flooding, roadside ditches, irrigation ditches, freshwater commercial fishing, marine commercial fishing, municipal water treatment, municipal and industrial use, and steam power cooling. Ribaudo et al. (1989) suggested a $1.15 cost estimate for a ton of eroded soil in the Corn Belt region in the United Sates.

Ribaudo et al. (1989) reported that navigation damage estimates were calculated assuming a linear relationship between sediment discharge and annual dredging costs, and that the navigation results are probably underestimated because "dredging and water transportation services are probably imperfect substitutes". This underestimation was not a direct concern, as minimal dredging occurs in the Black Creek watershed. However, sediment leaving the Black Creek does affect the sediment deposition in the Maumee River which eventually goes to the Toledo Harbor, where dredging is a major concern. A soil erosion benefit value was found for the Maumee River Basin for the purposes of dredging at $0.87 per ton of soil erosion (Cangelosi et al., 2001). The total cost of damage per ton of eroded soil is $2.24 expressed in 2000 dollars

On-site nutrient damage cost was calculated by finding the amount of money spent to purchase the nutrients, and damage was considered the amount of money lost by the landowner when purchasing these nutrients because the nutrients are not staying on the field to enhance crop production (Buckner, 2001). Buckner (2001) used the bulk rate cost of triple super phosphate as substitutes for benefit estimates of reducing phosphorus from agricultural lands. The on-site cost of nutrient damage was the bulk rate price for triple super phosphate (00-46-00) in 2003 which is $264/ton or $0.26/kg (Heartland Co-op, 2004).

Though many assumptions are involved, water quality trading does partially provide the social, or downstream, costs associated with nutrient reduction. A study by Fang and Easter (2003) quantified the cost-effectiveness of a water quality trade in southwestern Minnesota which involved the implementation of control measures (vegetation restoration, streambank erosion control and stabilization, and livestock exclusion plus stream bank erosion control) and assigned a social cost of $1.56 (average per trade including expenditures from failed trade transactions and post-construction site maintenance costs) for the cost per pound of phosphorus removed. It was assumed that the control measures have a lifespan of 20 years and an 8% discount rate was used for cost computations. The crop rotation used in this study was a corn-sugar beet-soybean system. It is important to note that the cost estimates provided for phosphorus reduction in this study are trade values and not nutrient damage values. This "willingness to pay" estimate is specific to the environmental compliance standards for the study area. However, these values were computed under observed market conditions and provide a measure as to what value a corporation is willing to pay to meet environmental regulations. For purposes of this research, the social costs associated with phosphorus reduction as estimated from Fang and Easter (2003) of $1.20 per pound ($2.65/kg) of phosphorus removed was used. This value is the average per trade amount for only those trades that occurred at various sites in the Fang and Easter (2003) study with the control measures in place assuming a 20 year lifespan and an 8% discount rate.

BMP Establishment and Maintenance Costs

The next step was to determine the establishment and maintenance costs. Total establishment costs include the cost to install the practices, as well as technical and field assistance. To bring the establishment costs to 2000 prices, the future value of the establishment cost was calculated based on the last year of BMP implementation during the Black Creek Project (equation 51) where C is cost, s is interest and t is time period).

$$FV(C) = C_t * (1+s)^t \quad (1)$$

Maintenance costs provided by Indiana NRCS (2003) were tabulated on an annual basis.

Benefits Versus Costs

A benefit-cost ratio (BCR) was computed. The BCR seeks to show the benefit of an activity per dollar of cost. If the BCR is greater than 1, the benefits outweigh the cost and the project is worthwhile. If less than 1, the costs outweigh the benefits and the project should be ceased or alternatives put in place.

Results

Monetary Value of Water Quality Improvement Benefits

The quantity of sediment and total P reduced due to BMP installation as predicted by SWAT and the cost estimate of the benefits received from the reduction is shown in Tables 2-3.

Table 2 Estimate of sediment reduction benefits received from implementation of BMPs in good condition ([1] Ribaudo et al. (1989) estimate, [2] Cangelosi et al. (2001)

Year	Damage per ton of erosion [1] ($)	Damage per ton of erosion [2] ($)	Total Damage per ton of erosion ($)	Smith-Fry		
				Sediment Reduction (tons)	Benefit ($)	Future Value (2000) ($)
1980	0.82	0.5	1.32	30	40	142
1981	0.89	0.55	1.44	213	306	1012
1982	0.94	0.58	1.52	122	185	574
1983	0.97	0.59	1.56	103	161	468
1984	0.99	0.61	1.6	120	192	526
1985	1.02	0.62	1.64	126	207	532
1986	1.04	0.64	1.68	82	138	333
1987	1.07	0.65	1.72	87	150	339
1988	1.1	0.67	1.78	110	196	417
1989	*1.15*	0.7	1.85	90	167	334
1990	1.19	0.73	1.92	390	749	1406
1991	1.23	0.76	1.99	222	442	778
1992	1.26	0.77	2.04	123	251	416
1993	1.28	0.78	2.06	188	387	602
1994	1.29	0.79	2.08	78	162	236
1995	1.32	0.81	2.13	55	117	160
1996	1.34	0.82	2.16	255	549	707
1997	1.34	0.82	2.16	234	506	611

1998	1.35	0.83	2.18	97	211	239
1999	1.38	0.84	2.22	173	383	408
2000	1.39	0.85	2.25	89	200	200
2001	-	*0.87*	-	-	-	-
Benefit				2,987	5,699	$10,442

Table 3 Estimate of phosphorus reduction benefits received from implementation of BMPs in good condition

Year	On-Site Damage per kg of P ($)	Trade Value per kg of P ($)	Total Damage per kg of P ($)	Smith-Fry		
				Total P Reduction (kg)	Benefit ($)	Future Value (2000) ($)
1980	0.15	1.53	1.68	35	58	206
1981	0.17	1.66	1.83	116	212	701
1982	0.18	1.75	1.93	69	134	415
1983	0.18	1.81	1.99	52	103	301
1984	0.19	1.85	2.04	69	141	386
1985	0.19	1.90	2.09	60	125	322
1986	0.19	1.94	2.14	69	147	356
1987	0.20	1.99	2.19	49	107	242
1988	0.21	2.05	2.26	55	124	265
1989	0.21	2.14	2.36	57	133	266
1990	0.22	2.22	2.44	183	448	841
1991	0.23	2.30	2.53	113	287	506
1992	0.24	2.36	2.59	77	198	328
1993	0.24	2.38	2.62	90	236	367
1994	0.24	2.41	2.65	36	95	138
1995	0.25	2.46	2.70	33	90	124
1996	0.25	2.49	2.74	132	362	465
1997	0.25	2.50	2.75	106	292	353

1998	0.25	2.52	2.77	74	206	234
1999	0.26	2.56	2.82	76	214	228
2000	*0.26*	2.60	2.86	59	168	168
2001	-	2.63	-	-	-	-
2002	-	2.64	-	-	-	-
2003	-	*2.65*	-	-	-	-
Benefit				1,610	$3,882	$7,213

BMP Maintenance and Establishment Costs

Historical literature from the Black Creek Project lists monetary values for establishing the practices (Tables 4). The future value of the $5,908 establishment costs, using a 6.5% interest rate for a 20-year time period, is $20,818, using equation 1.

Maintenance costs for the BMPs were estimated from the USDA NRCS 2003 cost list for Indiana, which includes the operation and maintenance costs for conservation practices in Indiana. Lengths for grassed waterway and field borders were measured from digital orthophotos. Total project BMP maintenance cost in 2000 dollars on an annual basis for the four structural BMPs is approximately $955 for the Smith-Fry watershed (Table 5). A total annual maintenance cost of $31,801was computed (Table 6).

Table 4 Smith-Fry watershed BMP establishment costs in 1980

BMP	Total area in Smith-Fry	Total unit cost	Total unit cost (Smith-Fry)
Field border	5920 ft	$0.30/ft	$1,776
Grade stabilization structure	2 rock drop structures, 2 overfall structures	$295 (/structure)	$1,180
Grassed waterway	2.3 ac	$755/acre	$1,767
Parallel terrace	1581 ft	$0.75/ft	$1,186
Total			$5,908

Table 5 Estimated maintenance cost per watershed in 2000 prices

BMP	Total area in Smith-Fry	Annual Maintenance Cost for Smith-Fry in 2000 Dollars

Field border	5920 ft	58
Grade stabilization structure	2 rock drop structures, 2 overfall structures	353
Grassed waterway	2.3 ac	172
Parallel terrace	1581 ft	372
Total	-	$955

Table 6 Annual estimated maintenance costs per watershed

Year	Annual BMP Maintenance cost ($) Smith-Fry	Future Value Maintenance cost ($) Smith-Fry (2000)
1980	562	1980
1981	610	2019
1982	645	2004
1983	664	1938
1984	681	1864
1985	697	1793
1986	713	1723
1987	731	1657
1988	755	1607
1989	788	1575
1990	817	1533
1991	846	1490
1992	866	1433
1993	876	1361
1994	884	1290
1995	903	1237
1996	916	1178
1997	919	1110
1998	927	1051

1999	942	1004
2000	955	955
total		$31,801

Benefits Versus the Costs

A benefit-cost ratio of 0.47 was calculated (Table 8). The costs for installing and maintaining the BMPs far exceeded the benefits received by the BMPs, producing a benefit-cost ratio less than 1.

Table 8 Benefit-cost ratio

Scenario	Benefits	Costs	B-C ratio		
	Sediment Reduction	Total P Reduction	Establishment costs	BMP Maintenance costs	
BMPs in good condition	$10,442	$7,213	$5,908	$31,801	0.470

Conclusion

Ten BMPs implemented over 20 years ago in a sub-watershed of a large watershed demonstration project, the Black Creek Project, were simulated in SWAT in varying conditions to quantify the sediment and total P reduction occurring as a result of BMP implementation. A monetary value was assigned to the improvement of water quality received by implementing grassed waterways, field borders, grade stabilization structures and parallel terraces. Benefits received from reducing soil erosion and total phosphorus were estimated to be $2.24/ton of soil and $2.86/kg of phosphorus (expressed in 2000 dollars). Establishment costs were obtained from project records, and maintenance costs were compiled using Indiana NRCS recommendations. All monetary values were expressed in real 2000 dollars using the producer price index from the U.S. Department of Labor.

Benefits and costs of BMP implementation were compared. The costs to establish and maintain the BMPs outweighed the benefits of the practices based only on sediment and phosphorus reduction from non-gully erosion as predicted by SWAT. Numerous benefits, including lessons learned by the conservation community, gully erosion prevention, deposition of soil throughout the watershed, nitrogen reduction, wildlife habitat improvement, human and aquatic ecosystem health, aesthetics, intangible impacts and the needs of future generations, were not captured because methods to quantify them are beyond the scope of this study. It is likely that the inclusion of these benefits would improve the benefit-cost ratio. Also, non-structural BMPs may be more cost-effective than the structural BMPs studied here. These findings show the need for improved tools to fully compare economic benefits and costs concerning water quality. Economic analyses such as this one using tools that do not allow for computation of a number of benefits should not be the sole determining factor when deciding if a conservation project is worthwhile .

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