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Economic Efficiency of Erosion and Water Pollution Control in an Agricultural Watershed

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Offsite damages from cropland erosion are becoming an increasingly important element in the design and evaluation of soil and water conservation programs. A major component of offsite damages is nonpoint source pollution. In a national assessment of USDA erosion control programs, Strobehn concluded that the offsite benefits of these programs account for about two-thirds of the total benefits of erosion control programs. Strobehn recommends that conservation programs should emphasize both the reduction in offsite damages and maintenance of soil productivity. Strobehn and Ribaudo point out that conservation programs designed to control erosion are not necessarily cost effective in reducing offsite damages. Due to the spatial and temporal discontinuities between on-farm erosion control and downstream sediment delivery, Crosson recommends that attention be shifted from reducing erosion on fields to reducing edge-of-field sediment delivery. Milon indicates that, lacking the ability to determine the socially optimal level of water pollution control, the selection of nonpoint source controls should be based on their cost effectiveness or economic efficiency.

Since erosion control is the centerpiece of current farm policies to conserve natural resources, the economic efficiency of erosion control criteria in reducing agricultural nonpoint source pollution is an important policy issue. This paper examines the social economic efficiency of three management strategies for reducing erosion and agricultural nonpoint source pollution in Idaho's Tom Beall watershed. Two of the strategies utilize erosion control criteria and the third strategy attempts to reduce water pollution by improving the management of riparian areas.

WATERSHED

The Tom Beall watershed is located in the lower end of Idaho's Lapwai Creek drainage. The watershed contains 4,563 hectares of cropland, primarily winter wheat, barley, peas and forage crops, and grazing land. Seventy-five percent of the cropland in the watershed is highly erodible due primarily to the steepness of the land and extensive use of conventional tillage (Shi). Most of the erosion in the watershed is caused by snowmelt runoff and winter rains in January and February. The estimated average annual erosion rate for Tom Beall watershed is 27.8 megagrams per hectare per year (MHY) with current land uses and farming practices. Cropland erosion results in runoff which carries large quantities of sediment to Tom Beall Creek.

PROCEDURES

Resource Management Systems

A resource management system (RMS) is a specific combination of cropping pattern, tillage practice (conventional, minimum or no tillage) and land treatment practice (up-and-down cultivation, contour farming, cross slope farming or divided slope farming). Eleven RMSs were analyzed: CTUD - conventional tillage with up-and-down cultivation; CTCS - conventional tillage with cross slope farming; CTCF - conventional tillage with contour farming; CTDS - conventional tillage with divided slope farming; MTCS - minimum tillage with cross slope farming; MTCF - minimum tillage with contour farming; MTDS - minimum tillage with divided slope farming; NTCS - no till with cross slope farming; NTCF - no till with contour farming; NTDS - no till with divided slope farming; and PV - permanent vegetation. Since CTCF is the most common system used in the watershed, it was selected as the baseline RMS.

Erosion Rates

Soil erosion rates for each field were calculated using the Universal Soil Loss Equation or USLE (Wischmeier and Smith). The K (soil erodibility) and LS (length and slope) factors in the USLE were obtained from soil surveys and topographic maps. The R (rainfall) factor was obtained from meteorological sources (NOAA). The C (cover) and P (practice) factors varied with the RMS used on each field.

Economic Returns

Since a wheat-pea rotation is the dominant rotation in the watershed, it was the only rotation considered. Variable and fixed costs per hectare pertain to an average size farm (405-hectares). A zero yield penalty was assumed for minimum tilled wheat and a 15% yield penalty for no tilled wheat. Peas were assumed to be conventionally tilled. Annualized net returns per hectare for each RMS were estimated using the Erosion Planning (EROPLAN) model with a 20-year evaluation period and a 4% real discount rate. The price of wheat equaled the 1987 target price of 16 cents per kilogram and the price of peas equaled the 1987 market level of 18 cents per kilogram. Real prices and costs were assumed to remain constant throughout the evaluation period. All land in PV was assumed to have an annualized net return of $148 per hectare which equals the current CRP rental rate in northern Idaho.

Water Quality

Changes in water quality at the outlet of the watershed were determined using the Agricultural Nonpoint Source (AGNPS) pollution model (Young et al.). This model simulates erosion, runoff, eroded and delivered sediment, nitrogen, phosphorus and chemical oxygen demand in runoff for individual storm events and land use practices. AGNPS has been used in several watershed studies (Crowder and Young; Frevert and Crowder; Prato et al.).

Watershed Management Strategies

The first erosion control strategy selects the RMSs that maximize annualized net return per hectare on every field in the watershed and that have erosion rates less than or equal to 1T (T=11.2 MHY). A 1T erosion limit is the soil loss tolerance (maximum erosion rate that preserves long-term soil productivity). The second erosion control strategy is similar to the first except that the field erosion limit is 1.5T. This higher erosion limit is the maximum rate permitted by the Idaho Soil Conservation Service (SCS) in developing conservation plans that satisfy the conservation compliance provision of the Food Security Act of 1985. The Idaho SCS can use the 1.5T rate whenever achievement of the 1T rate is expected to impose an economic hardship on farmers.

For the erosion control strategies, non-cropland areas in the watershed were treated with either poor or good vegetative cover. Non-cropland areas include areas occupied by the creek, trees and shrubs, and riparian areas adjacent to the creek that are not cropped. Currently, most riparian areas in Tom Beall watershed have poor vegetative cover. Good cover conditions can be achieved by planting grass, trees or shrubs in riparian areas now planted to wheat or peas.

The third strategy, called the riparian strategy, uses permanent vegetation on all fields adjacent to the creek, good vegetative cover on non-cropland areas and the most profitable RMS on all remaining cropland.[1] Vegetative filter strips between 66 and 99 feet wide are currently eligible for the Conservation Reserve Program (CRP). Since this strategy is aimed at reducing the movement of sediment and nutrients through the riparian zone to receiving waters, it is a water pollution control strategy.

RESULTS AND DISCUSSION

Resource Management Systems

While MTCF is the most economically efficient RMS for reducing erosion, it does not achieve the soil erosion limits on all fields. Of the 62 fields in the watershed, 48 exceeded the 1T limit and 36 exceeded the 1.5T limit with MTCF. Twenty-five fields exceeded the 1T limit and 11 exceeded the 1.5T limit with no tillage. All fields satisfied both erosion limits with PV. Although no tillage and PV meet the erosion limits more often than minimum tillage, they have a lower per acre net return than conventional or minimum tillage. Net returns were higher with minimum tillage than with conventional tillage because minimum tillage has lower per acre production costs and maintains greater topsoil depth than conventional tillage.

Table 1 shows the cropland area in each RMS for the three management strategies. Forty-four percent of the total area in the watershed is in

1. Since the widths of the fields adjacent to the creek exceed 99 feet, only a portion of the riparian areas would qualify as a CRP vegetative filter strips.

PV for the 1T erosion limit, 17% for the 1.5T limit and 15% for the riparian strategy. The remaining cropland area under the riparian strategy is treated with MTCF because it has the highest annualized net return per hectare of all RMSs.

Erosion and Income Effects

Table 2 shows total erosion, net farm income and the social economic efficiency of erosion reduction for the three management strategies. Total erosion decreased 77% for 1T, 62% for 1.5T and 47% for the riparian strategy. Reducing erosion on all fields to 1T caused net farm income to decline by 19.8% without cost sharing and 17.6% with cost sharing.[2] When field erosion rates were reduced to 1.5T, net farm income decreased 12.2% without cost sharing and 9.2% with cost sharing. Under the riparian strategy, net farm income decreased 4.5% without cost sharing and 1.1% with cost sharing. Net farm income is 9 to 20% higher, but total erosion is 39 to 131% greater with the riparian strategy than with the erosion control strategies. Net farm income is higher with than without cost sharing, however, total erosion is the same because the same RMSs are selected.

Social economic efficiency is the decrease in net farm income (without cost sharing) divided by the decrease in total erosion relative to the baseline. Net farm income without cost sharing is used to determine economic efficiency because cost sharing is a transfer payment from the federal government to farmers. Transfer payments do not affect social economic efficiency. The riparian strategy is the most economically efficient strategy for reducing erosion because it results in the lowest reduction in net farm income per kilogram of erosion reduction. However, the riparian strategy is less equitable than the erosion control strategies because those farmers who own or lease fields adjacent to the creek bear the income loss. Since net farm income is lower with the riparian strategy than with current practices, it is not possible to improve the total welfare of farmers by redistributing income.

Water Quality Effects

The effects of current practices and the three management strategies on water quality were analyzed by comparing the levels of total sediment, total nitrogen, total phosphorus and soluble chemical oxygen demand (COD) for four storm events, 10, 25, 50 and 100 years. Sediment, nitrogen, phosphorus and COD levels increased with storm intensity, but at a decreasing rate. The percentage decrease in pollution was greatest for the 10-year storm event and smallest for the 100-year storm event, and about 10 percentage points higher with good than with poor vegetative cover of non-cropland areas. Percentage reductions in pollution were highest for sediment followed by nutrients and COD.

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2. Cost sharing rates in northern Idaho are a maximum of $35 per hectare for minimum tillage and $49 per hectare for no tillage for a maximum of two years. One-time cost sharing payments for land treatment practices are: $20 per hectare for contour farming, $21 per hectare for divided slope farming and $82 per hectare for PV.

Average reduction in all four pollutants was 49% with poor vegetative cover and 70% with good vegetative cover at 1.5T and 68% with poor cover and 80% with the good cover at 1T.

The riparian strategy reduced average water pollution by 61%, which is less than the reduction for both erosion control strategies with good vegetative cover. However, pollution levels can be decreased more with the riparian strategy than with the 1.5T strategy when vegetative cover is poor (61% vs. 49%). Since all three strategies reduce runoff more than they reduce sediment, nitrogen, phosphorus and COD levels, pollutant concentrations are uniformly higher with the three management strategies than with current practices.

Economic Efficiency of Reducing Water Pollution

Table 3 compares the social economic efficiency of the three management strategies defined as the decrease in net farm income (without cost sharing) per unit reduction in pollution. The economic efficiency of reducing water pollution is greater for the riparian strategy than for the 1T or 1.5T strategy, and greater for the 1.5T strategy than for the 1T strategy. The 1T strategy is the least efficient of the three strategies because net farm income decreases proportionately more than pollution levels.

CONCLUDING REMARKS

This paper compares the social economic efficiency of three strategies for reducing erosion and water pollution in a dryland agricultural watershed in northern Idaho. For the watershed and resource management systems considered here, reducing erosion on all fields to 1T (11.2 megagrams per hectare per year) results in a 77% reduction in erosion, an 80% decline in average water pollution and an 18% (with cost sharing) to 20% (without cost sharing) decrease in net farm income. Reducing field erosion rates to 1.5T results in a 62% reduction in erosion, a 70% decline in average water pollution, and a 9% (with cost sharing) to 12% (without cost sharing) decrease in net farm income. While the riparian strategy results in the smallest decrease in erosion (47%), average water pollution (61%), and net farm income (1% with cost sharing and 4.5% without cost sharing), it is 65% more efficient than the 1.5T strategy and 75% more efficient than the 1T strategy in reducing water pollution in Tom Beall watershed.

In summary, the erosion control strategies generate less total erosion and water pollution than the riparian strategy, but are less efficient. However, the riparian strategy is less equitable than the erosion control strategies because farmers owning or leasing fields adjacent to the creek would experience a significant decline in net income whereas farmers with fields away from the creek would experience an increase in net income. Reductions in net farm income also occur with the erosion control strategies, but they are more evenly spread among farmers. Since the erosion and riparian strategies have disparate effects on efficiency and equity, it would be worthwhile considering how mixed erosion-water pollution control strategies affect efficiency and equity.

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Table 1. Cropland Area in Resource Management Systems for Alternative Management Strategies.

System	Erosion Control Strategy				Riparian Strategy	
	1T		1.5T			
	Area (hectares)	Percent	Area (hectares)	Percent	Area (hectares)	Percent
MTCF	684	19.22	1,561	43.86	3,018	85.82
MTDS	500	14.05	296	8.33	---	0
NTCF	673	18.91	808	22.72	---	0
NTDS	145	4.07	283	6.82	---	0
PV	1,556	43.75	610	17.14	540	14.18
Total	3,558	100	3,558	100	3,558	100

Table 2. Total Erosion, Net Farm Income and Social Economic Efficiency of Alternative Management Stategies

Strategy	Total Erosion[a] (10^3 kg)	Net Farm Income ($)		Social Economic Efficiency[b] ($/kg)
		With Cost Sharing	Without Cost Sharing	
Baseline[c]	134,014	795,092	789,974	----
1T	30,591	655,003	633,232	1.84
1.5T	50,884	722,138	693,706	1.40
Riparian	70,666	786,297	760,648	0.56

a. Calculated with USLE.

b. Change in net farm income (without cost sharing) divided by change in total erosion relative to baseline.

c. Conventional tillage with contour farming.

Table 3. Social Economic Efficiency of Alternative Management Strategies

Pollutant	Storm Event	Erosion Control Strategies 1.0T	Erosion Control Strategies 1.5T	Riparian Strategy
Sediment ($\$/10^3$ kg)	10	14.52	9.63	3.35
	25	9.58	6.38	2.27
	50	7.99	5.35	1.92
	100	6.74	4.54	1.65
Nitrogen ($/kg)	10	10.23	7.24	2.62
	25	7.30	5.21	1.94
	50	6.36	4.55	1.72
	100	5.57	4.00	1.52
Phosphorus ($/kg)	10	20.64	14.17	5.13
	25	14.70	10.25	3.78
	75	12.74	8.87	3.32
	100	11.20	7.85	2.95
COD ($/kg)	10	5.90	4.51	1.34
	25	4.42	3.54	1.04
	75	3.94	3.21	0.94
	100	3.54	2.93	0.86

SIZING MULTI-PURPOSE RESERVIORS:
A METHODOLOGICAL APPROACH AND APPLICATION

George Oamek and Larry Schluntz

INTRODUCTION

The original mission of the Bureau of Reclamation to construct large water resource projects soon will be fulfilled. Of increasing importance is the nation's demand for high quality water and the necessity for for effective, efficient water resource construction and management. Current objectives are to improve management and use of resources, which, in many cases are already in place. Accordingly, Reclamation is developing new analytical tools to aid in the planning of new projects and the management of existing ones.

The process of sizing a reservoir is an example of where such an analytical tool is appropriate. The Bureau of Reclamation has not had formalized criteria in the past regarding how large to construct a reservoir. Some Bureau regions have used a heuristic rule-of-thumb which states reservoirs should be built large enough so irrigation uses are never shorted more than 50 percent of normal in the most critical year of record, and no more than a cumulative 100 percent over any 10 year period. Municipal and industrial uses (M&I) should never experience shortages under this rule.

In response to the need for consistency and to examine the relationship between reservoir size and economic benefits. reclamation is overseeing the development of a modeling framework in which to estimate total and marginal benefits of alternative reservoir sizes. Benefits estimated within this framework can then be matched against marginal cost of reservoir construction to arrive at an economically optimal sized reservoir.

The economic benefit of a reservoir, as a whole, is the sum of benefits to individual sectors using water, whether their demand be for consumptive or nonconsumptive uses. Model development has so far concentrated on 3 sectors, irrigation, M&I, and instream flows. However, the analysis presented here will emphasize only irrigation and M&I demands. Other uses, including recreation, hydropower production, and flood control will be addressed in later phases of the reservoir sizing study. Several goals for modeling system, intended to maximize its utility were specified prior to model development. The goals which had a significant impact on design of the modeling system included:

(1) The models should be able to address annual and seasonal variation in water deliveries, and any priority of uses in times of shortage.

(2) All model components, or sectors, should be separable. For instance, the irrigation component should be able to stand alone without the other components.

(3) The methodologies used for each