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AN ECONOMIC ANALYSIS OF TARGETING SOIL CONSERVATION MEASURES

by

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Abstract

An Economic Analysis of Targeting Soil Conservation Methods

Glenn Fox*, Gloria Umali and Trevor Dickinson*****

This paper analyses the benefits that can be gained from targeting conservation measures. The Stratford Avon watershed in Perth County and the Big Creek watershed in Middlesex County, both located in southwestern Ontario, are used as case studies. Targeting criteria, which are used as proxies for measuring the parcels' contribution to off-farm damage, are based on the physical characteristics of the parcels. Alternative conservation tillage practices include fall chisel ploughing, ridge planting and no tillage.

At each level of the targeting criteria, the reduction in off-farm damage is estimated using the Guelph Model for Evaluating the Effects of Agricultural Management Systems on Erosion and Sedimentation (GAMES). Economic decision criteria for selecting farms that are targeted for conservation measures are based on the value of improved water quality under a conservation practice minus the on-farm costs of adaption of that practice.

The emerging concern over environmental quality has caused attention to shift from the on-farm problems of erosion to the off-farm benefits that can be gained from erosion control. Reorientation of conservation policies towards reduction of off-farm damages and targeting conservation measures to the major sources of sedimentation can result in greater efficiency in public policy. We conclude that further efforts in targeting conservation policies have the potential to improve the cost-effectiveness of soil conservation programs if technical and administrative problems can be overcome.

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In the long run, men hit only what they aim at.

Thoreau (1854)

I. INTRODUCTION

The idea of targeting soil conservation programs gained momentum when analysis of the 1982 Natural Resource Inventory (USDA, 1982) revealed that over half of all erosion on cropland in the United States occurred on about one-tenth of the cultivated acreage. This conclusion came close on the heels of the observations a year earlier that half of federal cost-sharing expenditures had been directed at land estimated to be eroding at a relatively low rate and that less than 20% of the practices introduced to control erosion had been installed on the most erosive land (USDA-ASCS, 1981). Soil conservation programs in the United States and Canada have traditionally been voluntary and non-targeted. Increasing pressure on the budgets of government agencies managing these programs has prompted a search for more cost-effective modes of program delivery. Unfortunately, the discussion in the literature has placed more emphasis on how to target than on what to hit. Identification of the target seems to us to be a logically prior step to the design of procedures to target.

Soil erosion has local and non-local consequences. On the farm, erosion can reduce organic matter content, weaken soil structure, diminish water holding capacity and thereby contribute to loss of productivity (Science Council of Canada, 1986). Off-site effects arise from sediment deposition in lakes and streams brought about by erosion from agricultural production sites (Foster and Meyers, 1977; Clark, *et. al.*, 1985). Displaced sediment can cause, among other things, increased flooding, reduced hydro-electric power and interference with irrigation (ASCE, 1975; Hudson, 1981; Clark, *et. al.*, 1985; Crosson, 1986). Estimates of the costs of off-farm damages have often been greater than the cost of productivity reduction on the farm (Crosson, 1984; Clark, *et. al.*, 1985; Fox and Dickson,

1989) so that programs and policies directed towards the reduction of soil erosion and sediment delivery may be more beneficial to water users than to farmers. In Central and Southwestern Ontario, agriculture makes a significant contribution to total sediment deposition (Erosion and Sedimentation Coordination Committee, 1983). Dumanski (1986) has estimated that the off-farm impacts of water erosion cause sediment damage of about $100 million annually. Dickson's (1988) work indicates that off-farm damage from sediment eroded from Ontario cropland causes damage ranging from $25 to $100 per hectare per year. On-farm productivity loss and nutrient value loss have been estimated at approximately $89 million annually (ESCC, 1983), but Fox and Dickson (1988) have argued that this over-states the true on-farm costs.

Traditionally, efforts to reduce soil erosion in Canada have been directed at the preservation of soil productivity. Several studies have indicated that soil conservation practices are generally not very attractive to farmers because their profitability is lower than the farmers' conventional practices (Stonehouse, *et.al.,* 1987; Dickson and Fox, 1989; Weersink and Walker, 1991). However, those same studies conclude that the off-farm benefits of erosion control can outweigh the on-farm costs. The nature of the net costs to producers of using production practices which reduce erosion has important consequences for the degree to which voluntary compliance can be expected, but is of little help in the identification of targets. The emerging consensus among agricultural economists is that the aim of soil conservation policy should be off-site water quality improvement (Clark et al., 1985, Chapter 7, McConnell, 1983, AAEA Soil Conservation Task Force, 1986, Van Kooten et al., 1989, Fox, 1992). Given that the on-site costs of erosion are borne by the farmer it has been argued that the farmer has an adequate incentive to take those costs into account when making crop production decisions. Under the current structure of ownership of surface water in Canada, producers have little incentive to worry about off-site damage done by eroded sediment (Dales, 1968, Fox, 1991).

In this paper, we have elected to use improvement in off-site water quality as our target. Fox

and Taff (1990) have proposed a targeting scheme that would select problem areas and focus treatment on the basis of off-site damage. They suggest that the first step in targeting is the selection of the watershed for which improvement in water quality would result in the greatest reduction in off-site damages. The second step entails the selection of farms within the watershed for which conservation efforts would be most cost-effective in reducing the contribution in water quality problems at the watershed. Previous research on targeting soil conservation has used various targeting criteria. Clark, *et. al.* (1985) employed a measure of critical soil erosion rates based on the soil loss tolerance values. Dickinson, *et. al.* (1986) used soil detachment, surface roughness and slope as the criteria for determining critical erosion areas. Runge, *et. al.*, (1986) employed a productivity reduction index for designating problem areas.

II. DATA AND PROCEDURES

We have elected to use two southwestern Ontario watersheds, the Stratford Avon watershed and the Big Creek watershed, as case studies. These watersheds have been the subject of previous work by Dickinson et al and by Fox and Dickson.

The Stratford Avon watershed is in the North Thames River Basin in Perth County. The watershed covers 537 hectares, 60 per cent of which is cultivated cropland. The predominant crop is corn and the conventional tillage is Fall Moldboard Ploughing (FMP). The topography is rolling with slopes ranging from 0.1 to 11.8 per cent. For this study, a crop rotation of alternating two years corn and two years alfalfa (2C2A) is considered as the conventional crop rotation in the area.

The Big Creek Watershed is in the mouth of the Thames River on the eastern end of Essex County. The watershed covers 3,300 hectares. The predominant crops are corn, soybeans and tomatoes and the conventional tillage is fall moldboard ploughing. The landscape is mainly flat with slopes of no more than 2 per cent. Alternating one year corn, one year soybeans (CS) is considered

in the analysis as the conventional crop rotation in the area.

For Stratford Avon, the conservation practices that will be used are 2C2A/Fall Chisel Ploughing (2C2A/FCH) and 2C2A/No Till (2C2A/NT). For Big Creek it will be CS/FCH and CS/Ridge Planting (CS/RPL). The conservation practices that will be introduced involve a change in the tillage practice only; the current crop rotation will be retained. Permanent grass buffer strips along waterways were also considered for the Big Creek watershed.

The Guelph Model for Evaluating the Effects of Agricultural Management Systems on Erosion and Sedimentation (GAMES[1/]), developed at the School of Engineering of the University of Guelph, was used to simulate the effects of changes in production practices on erosion and sediment deposition. Changes in management practices are incorporated by changing the cropping factor (C-factor) value which represents the effect of cover and management variables. For a new C-factor value, the model estimates new values of gross erosion and sediment delivery for each parcel of land. Total gross erosion from all the parcels and sediment loading to the stream for the whole watershed are also computed.

Data for the physical characteristics of each parcel in the watershed were obtained from the data base of the School of Engineering at the University of Guelph. For the Stratford Avon watershed, the C-factors in the data set correspond to continuous corn with fall moldboard ploughing while for Big Creek watershed, the C-factors correspond to alternating corn and soybeans. More recent computations of continuous corn C-factors for the Stratford Avon watershed were obtained from Mohr (1988). These values were used here since they accurately account for the current management practices in the area (pers. comm., Irene Shelton, Dept. of Land Resources). The C-factors obtained from Mohr had to be adjusted to reflect the switch from continuous corn (CC) to alternating 2 years of corn and 2 years of alfalfa. Adjustment of C-factors from CC to 2C2A was

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[1/] See Dickinson and Rudra (1990) for a comprehensive description of the model.

based on data for Middlesex county (Kingston, 1990) which give the C-factors for both CC and 2C2A. The Middlesex county values show that the C-factor for 2C2A is 44% lower than the C-factor for CC therefore the C-factor used for 2C2A was set equal to .56 of the CC C-factor.

Dickson (1988) estimated the on-farm costs of adoption of different conservation practices. For alternative crop rotation and tillage combinations, he estimated the net returns and compared this value to the net returns under conventional practice. The reduction in net returns is taken as the cost of switching from conventional to conservation practices. The on-farm costs of adoption of conservation practices are shown in Table 1.

Dickson used a budgeting approach to estimate the value of the improvement in water quality in terms of the off-farm benefits accruing to sport fishing, water conveyance and water treatment. These estimates are shown in Table 2. These values and the costs of adoption are used in the estimation of the net benefits that can be gained from the adoption of conservation practices.

The GAMES model was run for the conventional tillage system for each watershed. Then, using one of the targeting criteria, land which exceeded a critical value of that criterion was converted to one of the conservation measures. Successively lower critical values for the targeting criterion brought larger areas of land under the conservation practice until, eventually, all of the watershed was using the stipulated form of conservation tillage.

The physical variables that were used for targeting the cells for conservation measures are slope, sediment delivery ratio, rate of sediment delivery and proximity to the stream. Sediment delivery ratio is the percentage of soil loss that is deposited in the stream as sediment. Rate of sediment delivery is the amount of sediment, in metric tons per hectare, that a parcel deposits into the stream. Slope was used as a targeting criterion for Stratford Avon, since the area exhibits a rolling landscape. In the case of Big Creek, which is mainly flat, slope was not used as a targeting criterion. Instead, cells closest to the stream were retired from agricultural activities and put into

permanent grass.

Estimating Costs and Benefits of Targeting

Using the estimates from Dickson (1988) (Tables 1 and 2), costs of adoption were computed by multiplying the per hectare reduction in net returns by the total area under the conservation practice. Benefits to sport fishing and water treatment were estimated by multiplying the annual value of the benefits by the sediment reduction from the land area targeted for conservation practices. Benefits to water conveyance were obtained by multiplying the annual value of the benefit by the percentage reduction in erosion. The net benefits from adoption of conservation practices are calculated as the difference between the off-farm benefits and the on-farm costs.

Targeting the parcels that cause the most damage first and successively including less damaging parcels until the maximum net benefits from conservation are obtained will give the relationship between costs of and benefits from adoption of conservation measures that is shown in Figure 1. Because the per hectare cost of adoption is assumed to be the same across all farms, the curve corresponding to the cost of adoption of conservation measures is linear with respect to the area under conservation. Because parcels are placed under conservation tillage based on their contribution to off-site damage, the benefits per acre are high initially, but decrease as more area is brought under conservation measures.

The land area of a watershed that falls under each level of a targeting attribute is generally not linear. For example, if the slope in the watershed varies from 1% to 10%, it does not follow that 10% of the land has a slope of 1%, the next 10% a slope of 2% and so on. Using these physical attributes as the targeting criteria results in a non-linear relationship between the cost of adoption and the proportion of land under conservation. As a result the benefit curves reported later are not smooth functions of the targeting criteria.

III. RESULTS

The Stratford Avon Watershed

In this watershed, the GAMES model was used to identify parcels of farmland on the basis of sediment delivery rate, sediment delivery ratio and slope. In each case, a conservation practice was applied first to the land with the highest value of the targeting criterion. Subsequent model runs were used to estimate the reduction of sediment downstream as area under the conservation expanded. No-Till and Fall Chisel Ploughing were used as the conservation practices for model simulations in this watershed. Sediment delivery rate, sediment delivery ratio and slope were used as targeting criteria. This results in 6 sets of simulations.

The results for No-Till using the Sediment Delivery Rate to select priority parcels of land are reported in Table 3 and Figure 2. A blanket policy would place the 60% of the land area in the watershed devoted to crop production under No-Till. The net benefits of this non-targeted strategy are about 35% less than those obtained by using No-Till only on land with a sediment delivery rate greater than 0.2 mt/ha/yr. This strategy would put 24% of the watershed under this conservation practice.

The results when Fall Chisel Ploughing is used as the conservation practice and the sediment delivery ratio is used as the targeting criterion are reported in Table 4 and Figure 3. Once again, the net benefits from the non-targeted blanket policy are substantially less than the highest value of net benefits. Highest net benefits are achieved when land with a sediment delivery ratio higher than 0.06% is put under the conservation practice. This amounts to about 16% of the land area in the watershed. The results when No-Till is used as the conservation practice and Slope is used to target parcels of land are reported in Table 5 and Figure 4.

Summary of Results for Stratford Avon

Table 6 summarizes the results for the six simulations for Stratford Avon watershed. The table shows that an increase in net benefits under targeting of 47% to 94%, compared to a blanket strategy. The highest increase can be gained by using rate of sediment delivery as the basis for targeting while the least gain in net benefit results from using sediment delivery ratio. The increase in net benefit due to targeting comes from the substantial decrease in adoption cost when a smaller area is put under conservation.

Results for Big Creek Watershed

Essentially all of the 3300-hectare Big Creek watershed is devoted to agriculture. Because the parcels do not exhibit significant differences in slope, the targeting criteria were based on the rate of sediment delivery and on the sediment delivery ratio. An entirely different approach was used as a third targeting criterion. Parcels closest to the stream were targeted for retirement from agricultural activities and used as buffer zones to hinder sediment from reaching the stream by putting those parcels into permanent grass. The C-factor that was used for this third strategy was 0.20 which is the C-factor value for hay/pasture.

Table 7 gives the summary of results for targeting farms based on the rate of sediment delivery when Fall Chisel Ploughing is used as the conservation practice. Even if the target levels were varied in increments of .1 ton per hectare, the reduction in sediment and erosion can be attributed mainly to the size of the land area that gets included for targeting. This means that because the watershed is almost level, the parcels do not exhibit significant differences in the rate of sediment delivery. Unless an extensive area is targeted for conservation measures, targeting based on this characteristic does not result in a significant gain in benefits (Figure 5). Compared to the Stratford Avon watershed, a 6% increase in the targeted area (from 12% to 18%) brought about a

3% increase in net benefits, whereas for Big Creek, a 15% increase in the targeted area can only result in .28% increase in net benefit.

Using ridge planting as the tillage practice for conservation gives a higher net benefit than fall chisel ploughing when rate of sediment delivery is used as the targeting criterion. Ridge planting is a form of row crop tillage which leaves crop residue in the soil surface between crop rows. The results for this section are shown in Table 8 and Figure 6. In contrast to Stratford-Avon, targeting does not seem to have the potential to substantially improve net benefits.

Unlike Stratford Avon, sediment delivery rate did not yield significantly better results than sediment delivery ratio in Big Creek (Table 9 and Figure 7). Because Big Creek does not exhibit significant differences in physical characteristics the sediment delivery ratio does not vary much from parcel to parcel. The highest net benefit was obtained after more than 90% of the watershed was put under conservation, which is about the same land area (89%) that was necessary to get the highest benefit from sediment delivery rate.

In a topographically homogeneous watershed like Big Creek, targeting on the basis of physical attributes like slope or sediment delivery rate is problematical. We therefore elected to analyse the use of buffer-strips of permanent grass along the banks of watercourses in this watershed. These buffer strips capture eroded sediment before it reaches the stream. We considered strips from 50 metres to 160 metres in width. In these simulations, the adoption cost is the loss of income under the conventional tillage system, since the buffer strip was assumed to generate no income.

Table 10 reports the results of these simulations. It is evident from the results that when more than 8.5% of the land area is included in the buffer strips, on-farm cost exceeds off-farm benefits.

Summary of Results for Big Creek

Table 11 summarizes the results for the Big Creek watershed. The table shows that net benefits increase by at most 8.4% with targeting using the topographic characteristics of the watershed. However, the use of buffer strips of permanent grass shows potential.

IV. DISCUSSION

Our results suggest that physical characteristics may be used as proxy criteria for determining the farms that contribute the most off-farm damage. When conservation practices are targeted to parcels of land that cause the most off-farm damage, the cost effectiveness of conservation policies can be improved. In the Stratford Avon watershed, net benefits rose by 47% by targeting no tillage practices on the basis of the parcels' sediment delivery ratio and by 94% by targeting fall chisel ploughing based on sediment delivery rate. Because the parcels that contribute the most off-farm damage have been identified, the reduction in off-farm benefits is lower than that of on-farm costs. For example, the 94% increase in net benefits was attained through 70% decrease in on-farm costs with only a 26% reduction in off-farm benefits.

Targeting conservation measures in the Big Creek watershed could generate $88,000 a year in net benefits, indicating a minimal improvement from targeting. A buffer strip that hinders sediment from reaching the waterways may be a better strategy to reduce the off-farm damage in this situation. Targeting permanent grass to parcels along the waterways can reduce off-farm damage by $36,306.56. This is attained at an on-farm cost of only $480.92. The buffer strip can be built by sacrificing the agricultural income from an area of 2.2 hectares.

In the past, conservation policies have been based on farmers' willingness to participate in the program. More often than not, a farmer would try to get assistance from conservation programs to improve the quality of his land, to prevent soil loss or to reduce on-farm costs of erosion. However,

farmers in general do not have the incentive to reduce the off-farm damages caused by erosion because those costs are borne by others. But because conservation resources are scarce, targeting of remedial measures may be used so that the most benefit is attained at the least cost.

This study considered two types of watersheds in Southwestern Ontario. Targeting conservation practices worked very well for Stratford Avon where physical characteristics are variable from one parcel to another. In Big Creek, parcels have almost uniform characteristics. In this situation, a buffer strip may be a more effective way of mitigating sediment problems. Other watersheds that were not studied here will have other characteristics and maybe other criteria not explored here may be used as instruments for targeting farms for conservation practices.

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Table 1. Annual On-farm Costs of Adoption of Conservation Practices[1]

Watershed	Rotation/Tillage	Annual Net Returns[2]	On-farm Costs of Adoption
Big Creek	CS/FMP	$218.60/hectare	- conventional practice -
	CS/FCH	$201.83 / hectare	$16.77 / hectare / year
	CS/RPL	$184.91 / hectare	$33.69 / hectare / year
Stratford Avon	2C2A/FMP	$39.23 / hectare	- conventional practice -
	2C2A/FCH	$33.42 / hectare	$ 5.80 / hectare / year
	2C2A/NT	$28.78 / hectare	$10.45 / hectare / year

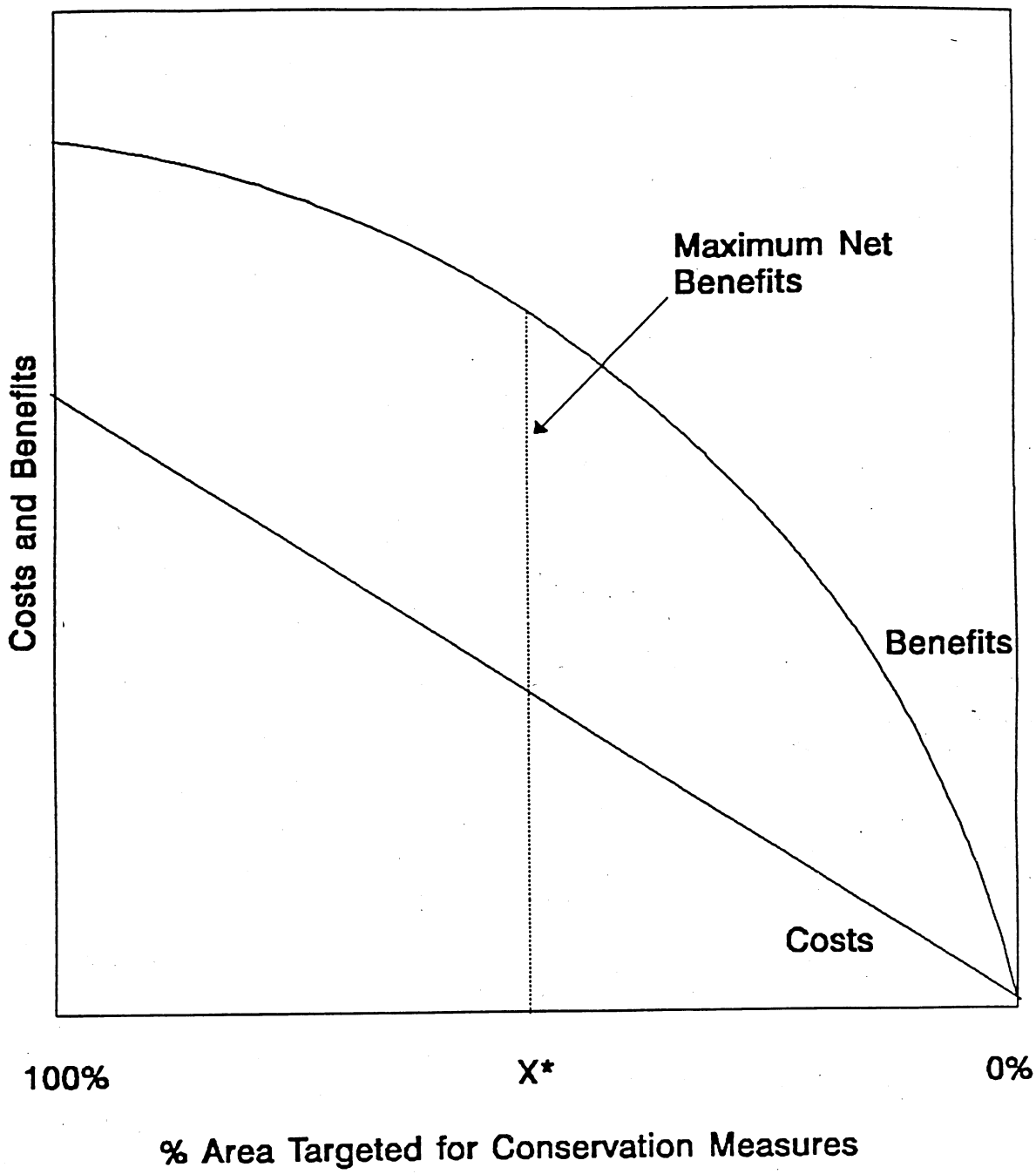
[1] Source: Dickson, 1988. An Economic Assessment of Benefits Arising from Adoption of Conservation Tillage Practices in Southwestern Ontario.

[2] In 1988 dollars.

Table 2. Off farm Benefits from the Adoption of Conservation Practices

Watershed	Beneficiary	Annual Value
Big Creek	Sport Fishing	$80.60 / ton of sediment reduction
	Water Treatment	$20.16 / ton of sediment reduction
	Water Conveyance	$112.50 / 1% reduction in erosion
Stratford Avon	Sport Fishing	$26.87 / ton of sediment reduction
	Water Treatment	$6.72 / ton of sediment reduction
	Water Conveyance	$18.31 / 1% reduction in erosion

Figure 1 **Expected Costs and Benefits from Targeting.**



X* - the optimal amount of conservation

Table 3. Results from Targeting on Rate of Sediment Delivery, Stratford Avon Watershed

Conservation Measure - 2C2A/NT

Sediment Delivery Rate (m.t./ha/yr)	Area (Ha.) Targeted	Sediment Reduction (metric tons)	% Reduction in Erosion	Cost ($) of Adoption	Benefit ($) to Sport Fishing	Benefit ($) to Water Treatment	Benefit ($) to Water Conveyance	Total Benefit ($)	Net Benefit ($)
RATE>0	322.5	113.37	82.07	3370.13	3046.33	761.87	1502.66	5310.87	1940.75
RATE>.2	126.7	104.99	54.07	1324.02	2821.14	705.55	990.10	4516.79	3192.78
RATE>.4	78.2	96.73	39.01	817.19	2599.08	650.01	714.20	3963.30	3146.11
RATE>.6	56.8	89.40	31.85	593.56	2402.04	600.73	583.21	3585.98	2992.42
RATE>.8	51.1	87.07	30.52	534.00	2339.49	585.09	558.91	3483.49	2949.49
RATE>1	40.7	80.32	25.54	425.31	2158.09	539.72	467.58	3165.39	2740.07
RATE>1.3	33.1	73.57	20.46	345.89	1976.69	494.36	374.56	2845.60	2499.70
RATE>1.5	29.5	69.96	18.86	308.28	1879.72	470.11	345.40	2695.23	2386.96
RATE>1.8	26.6	67.16	17.66	277.97	1804.66	451.33	323.36	2579.36	2301.39
RATE>2.2	19.1	57.73	11.88	199.60	1551.32	387.97	217.57	2156.87	1957.27
RATE>2.4	16.7	53.66	10.81	174.52	1441.85	360.60	197.91	2000.35	1825.84
RATE>3	10.6	42.49	6.06	110.77	1141.60	285.51	110.88	1537.98	1427.21
RATE>5	3.9	27.70	2.30	40.76	744.38	186.16	42.05	972.59	931.84
RATE>7	2.5	19.79	1.65	26.13	531.70	132.97	30.18	694.85	668.73
RATE>12	0.5	6.05	0.36	5.23	162.64	40.67	6.67	209.98	204.76

Figure 2

Costs and Benefits from No Tillage, Stratford Avon Targeting Based on Rate of Sediment Delivery

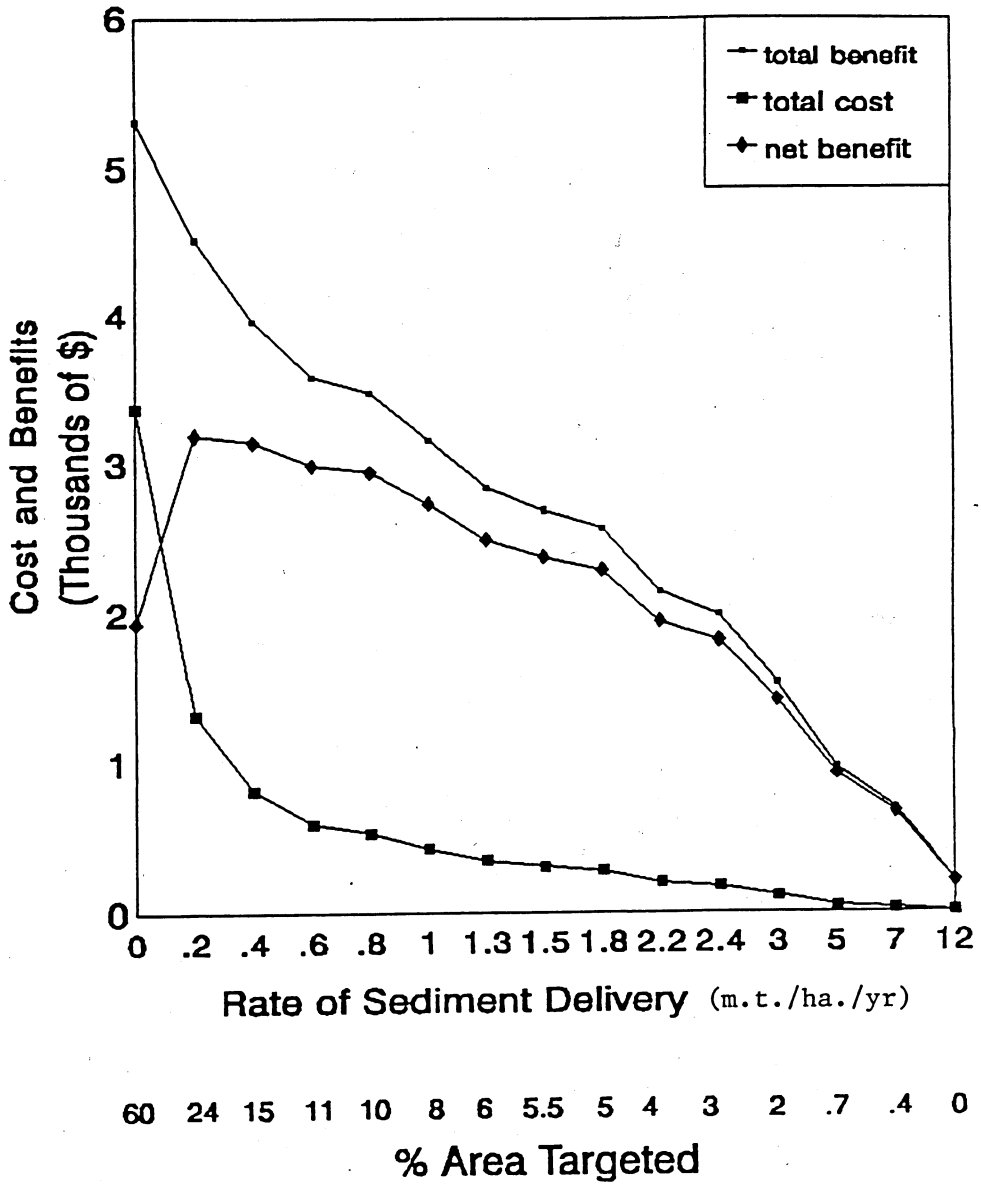


Table 4. Results from Targeting on Sediment Delivery Ratio, Stratford Avon.

Conservation Practice - 2C2A/FCH

Sediment Delivery Ratio (%)	Area (ha.) Targeted	Sediment Reduction (tons)	% Reduction in Erosion	Cost ($) of Adoption	Benefit ($) to Sport Fishing	Benefit ($) to Water Treatment	Benefit ($) to Water Conveyance	Total Benefit ($)	Net Benefit ($)
DR>0	322.5	57.15	41.19	1870.50	1535.67	384.06	754.21	2673.96	803.46
DR>.01	261.9	56.80	35.10	1519.02	1526.30	381.72	642.66	2550.67	1031.65
DR>.02	192.8	54.94	27.85	1118.24	1476.26	369.20	509.85	2355.31	1237.07
DR>.03	146.3	52.61	22.59	848.54	1413.71	353.56	413.56	2180.82	1332.28
DR>.04	124.1	50.75	19.55	719.78	1363.65	341.04	357.95	2062.65	1342.87
DR>.05	99.3	48.89	17.27	575.94	1313.62	328.53	316.13	1958.27	1382.33
DR>.06	88.3	47.72	16.20	512.14	1282.34	320.71	296.69	1899.73	1387.59
DR>.07	72.3	43.30	12.69	419.34	1163.50	290.98	232.38	1686.85	1267.51
DR>.08	69.6	43.07	12.52	403.68	1157.24	289.42	229.21	1675.86	1272.18
DR>.09	62.1	40.74	11.06	360.18	1094.68	273.77	202.43	1570.88	1210.70
DR>.1	47.5	33.99	7.31	275.50	913.28	228.41	133.93	1275.61	1000.11
DR>.2	13.0	20.60	2.27	75.40	553.60	138.45	41.59	733.64	658.24
DR>.3	6.2	17.69	1.60	35.96	475.41	118.90	29.39	623.69	587.73
DR>.5	3.3	12.69	0.99	19.14	340.93	85.26	18.08	444.26	425.12
DR>.6	2.5	8.38	0.60	14.50	225.20	56.32	10.96	292.47	277.97

Figure 3

Costs and Benefits from Fall Chisel Ploughing, Stratford Avon
Targeting Based on Sediment Delivery Ratio

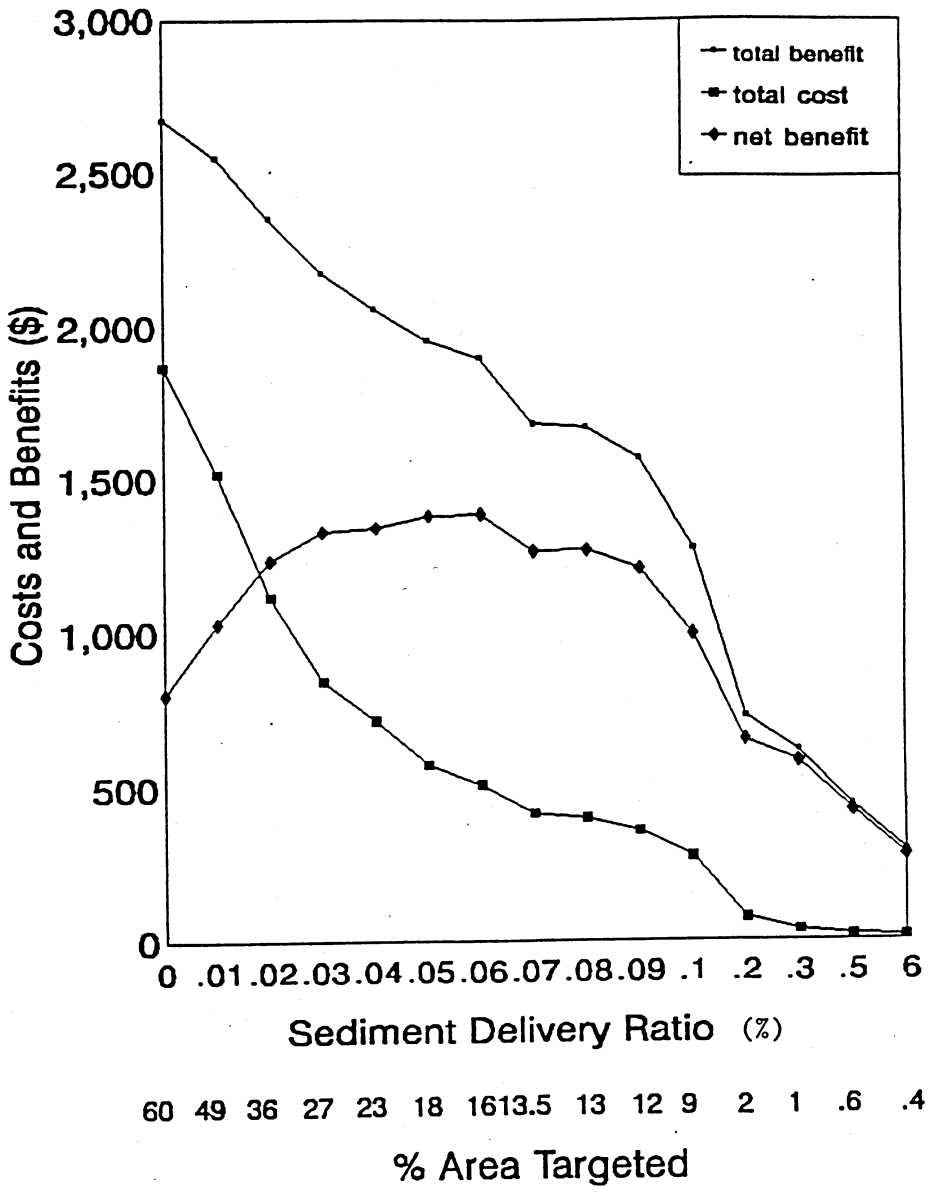


Table 5. Results from Targeting Based on Slope, Stratford Avon

Conservation Measure - 2C2A/NT

Sediment Delivery Rate (m.t./ha/yr)	Area (Ha.) Targeted	Sediment Reduction (tons)	% Reduction in Erosion	Cost ($) of Adoption	Benefit ($) to Sport Fishing	Benefit ($) to Water Treatment	Benefit ($) to Water Conveyance	Total Benefit ($)	Net Benefit ($)
SLOPE>.0	322.5	113.37	82.07	3370.13	3046.34	761.87	1502.66	5310.87	1940.75
SLOPE>.5	281.9	111.98	80.45	2945.86	3008.81	752.48	1473.05	5234.34	2288.49
SLOPE>.7	272.7	111.98	79.76	2849.72	3008.81	752.48	1460.39	5221.68	2371.97
SLOPE>.8	268.0	111.74	79.29	2800.60	3002.55	750.92	1451.80	5205.27	2404.67
SLOPE>.9	255.1	111.28	78.28	2665.80	2990.04	747.79	1433.27	5171.10	2505.30
SLOPE>1	250.4	111.05	77.99	2616.68	2983.79	746.22	1427.95	5157.96	2541.28
SLOPE>2	206.9	107.09	73.12	2162.11	2877.45	719.63	1338.78	4935.85	2773.75
SLOPE>3	139.9	98.47	62.33	1461.96	2646.00	661.75	1141.32	4449.07	2987.11
SLOPE>4	95.4	90.44	52.40	996.93	2430.19	607.77	959.35	3997.32	3000.39
SLOPE>5	53.0	68.21	35.15	553.85	1832.81	458.37	643.56	2934.74	2380.89
SLOPE>6	25.8	43.30	20.23	269.61	1163.49	290.98	370.49	1824.96	1555.35
SLOPE>7	10.1	28.40	9.04	105.55	763.15	190.86	165.47	1119.48	1013.93
SLOPE>8	7.3	22.35	6.73	76.29	600.51	150.18	123.20	873.89	797.61
SLOPE>9	3.0	4.42	2.86	31.35	118.85	29.72	52.44	201.02	169.67

Figure 4

Costs and Benefits from No Tillage, Stratford Avon Targeting Based on Slope

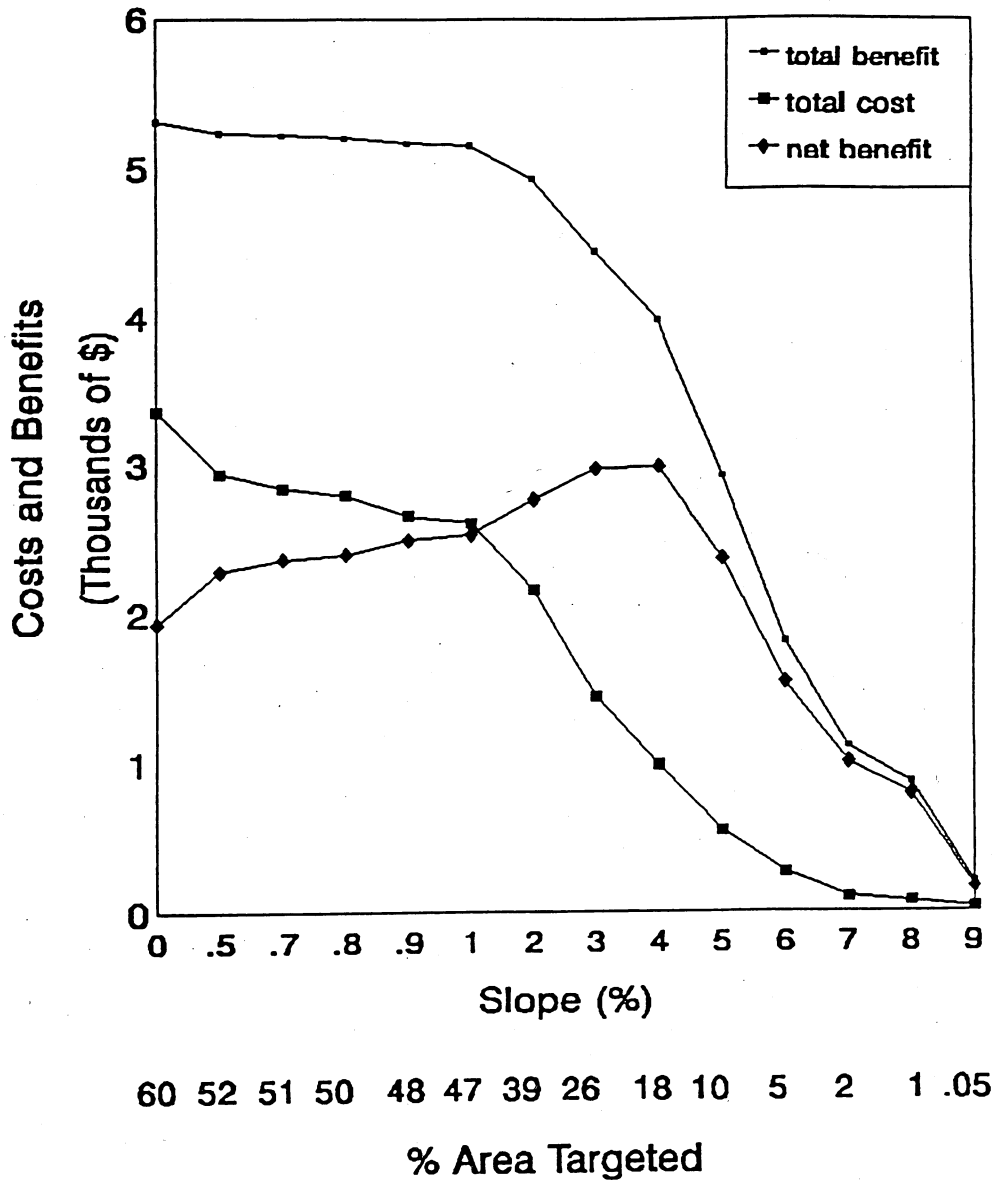


Table 6: Increased Net Benefit Due to Targeting, Stratford Avon

Conservation Measure	Target Variable and Level	% Area Targeted	Net Benefits	
			Amount ($)	% Increase
2C2A/FCH	ALL	60	803.46	–
	RATE ≥ .30	18	1555.72	94
	DR ≥ .06	16	1387.59	73
	SLOPE ≥ 4	18	1460.83	82
2C2A/NT	ALL	60	1940.75	–
	RATE ≥ .20	24	3192.78	64
	DR ≥ .06	16	2845.18	47
	SLOPE ≥ 4	18	3000.39	55

Table 7: Results from Targeting on Rate of Sediment Delivery, Big Creek

Conservation Measure - CS/FCH

Sediment Delivery Rate (m.t./ha/yr)	Area (Ha.) Targeted	Sediment Reduction (tons)	% Reduction in Erosion	Cost ($) of Adoption	Benefit ($) to Sport Fishing	Benefit ($) to Water Treatment	Benefit ($) to Water Conveyance	Total Benefit ($)	Net Benefit ($)
RATE>0	3269.7	1312.11	43.59	54832.87	105756.31	26452.20	4903.59	137112.10	82279.23
RATE>.1	3226.4	1312.11	42.80	54106.73	105756.31	26452.20	4815.14	137023.70	82916.92
RATE>.2	3170.5	1306.83	42.44	53169.29	105330.58	26345.71	4774.07	136450.40	83281.08
RATE>.3	2935.0	1273.24	39.49	49219.95	102623.36	25668.57	4442.82	132734.80	83514.80
RATE>.4	2456.5	1178.98	32.92	41195.51	95025.67	23768.21	3703.43	122497.30	81301.80
RATE>.5	2121.9	1094.47	28.04	35584.26	88213.95	22064.43	3154.75	113433.10	77848.87
RATE>.6	1685.3	956.32	21.70	28262.48	77079.41	19279.42	2440.72	98799.54	70537.06
RATE>.7	1484.1	882.64	18.80	24888.36	71140.99	17794.07	2114.98	91050.04	66161.68
RATE>.8	1090.4	715.92	13.68	18286.01	57703.12	14432.94	1538.52	73674.58	55388.58
RATE>.9	955.5	649.28	11.69	16023.74	52332.34	13089.58	1314.92	66736.84	50713.10
RATE>1	756.8	540.39	8.94	12691.54	43555.71	10894.33	1006.22	55456.26	42764.72
RATE>1.1	382.4	315.97	4.28	6412.85	25467.53	6370.04	481.97	32319.55	25906.70
RATE>1.2	35.7	90.61	0.36	598.69	7302.95	1826.64	40.40	9169.99	8571.30
RATE>1.3	3.5	67.72	0.03	58.70	5458.11	1365.20	3.49	6826.80	6768.11
RATE>1.4	0.6	65.42	0	10.06	5272.53	1318.79	0.54	6591.86	6581.80

Figure 5

Costs and Benefits from Fall Chisel Ploughing, Big Creek Targeting Based on Rate of Sediment Delivery

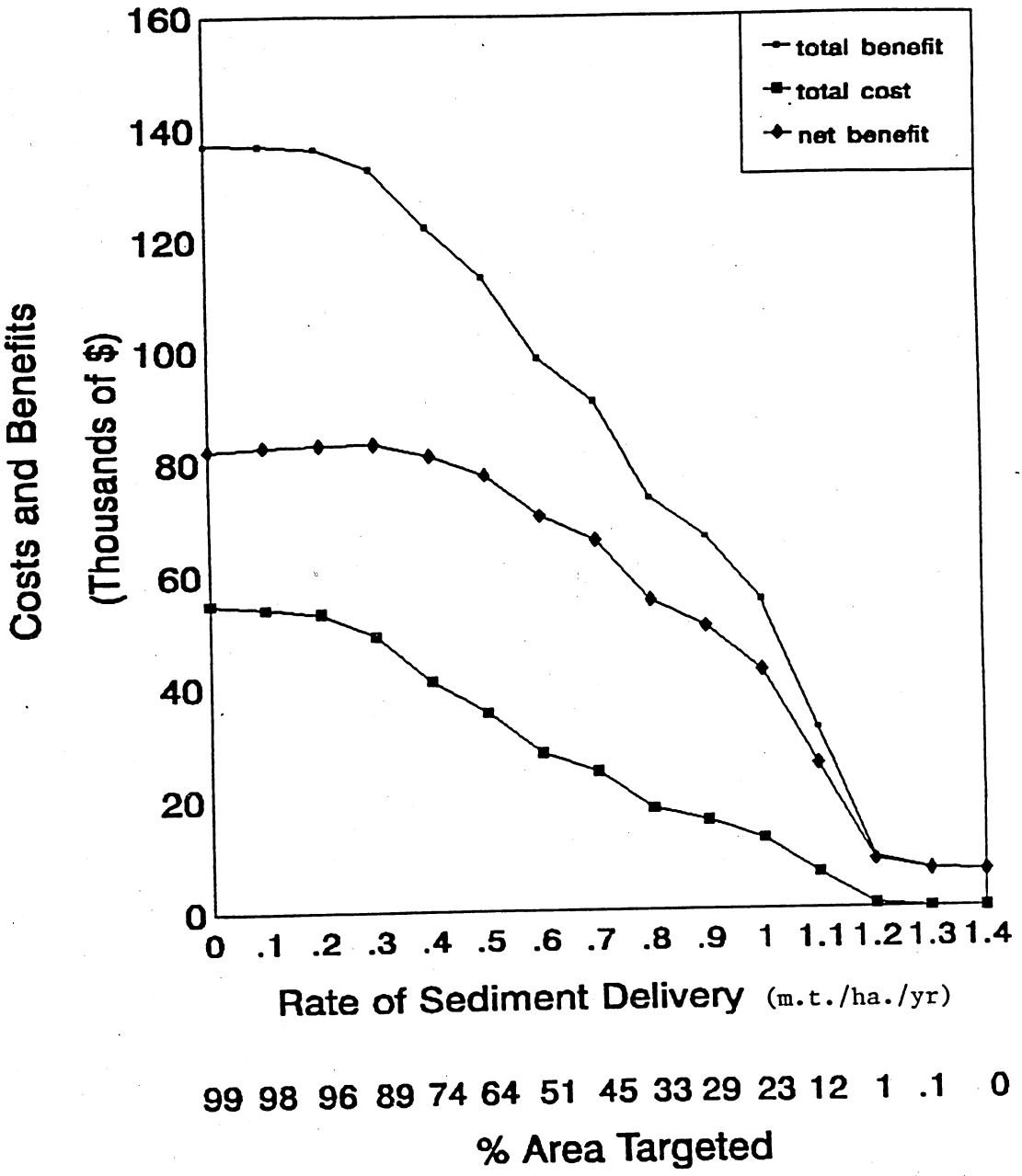


Table 8: Results from Targeting on Rate of Sediment Delivery, Big Creek

Conservation Measure CS/RP

Sediment Delivery Rate (m.t./ha/yr)	Area (Ha.) Targeted	Sediment Reduction (tons)	% Reduction in Erosion	Cost ($) of Adoption	Benefit ($) to Sport Fishing	Benefit ($) to Water Treatment	Benefit ($) to Water Conveyance	Total Benefit ($)	Net Benefit ($)
RATE>0	3269.7	1825.69	61.54	110156.20	147150.61	36805.91	6922.74	190879.30	80723.06
RATE>.1	3226.4	1825.69	60.42	108697.40	147150.61	36805.91	6797.78	190754.30	82056.88
RATE>.2	3170.5	1818.24	59.91	106814.10	146550.21	36655.74	6739.93	189945.90	83131.74
RATE>.3	2935.0	1770.84	55.75	98880.15	142729.54	35700.09	6272.32	184702.00	85821.81
RATE>.4	2456.5	1637.70	46.47	82759.48	131998.90	33016.10	5228.39	170243.40	87483.90
RATE>.5	2121.9	1518.38	39.59	71486.81	122381.71	30610.61	4453.70	157446.00	85959.20
RATE>.6	1685.3	1323.35	30.63	56777.76	106662.36	26678.82	3445.60	136786.80	80009.02
RATE>.7	1484.1	1219.34	26.54	49999.33	93278.70	24581.87	2985.77	125846.30	75847.01
RATE>.8	1090.4	983.95	19.31	36735.58	79306.32	19836.42	2172.02	101314.80	64579.18
RATE>.9	955.5	889.82	16.50	32190.80	71719.55	17938.78	1856.34	91514.67	59323.88
RATE>1	756.8	736.24	12.63	25496.59	59340.56	14842.50	1420.54	75603.60	50107.01
RATE>1.1	382.4	419.31	6.05	12883.06	33796.61	8453.35	680.34	42930.29	30047.24
RATE>1.2	35.7	101.17	0.51	1202.73	8154.41	2039.62	57.18	10251.21	9048.47
RATE>1.3	3.5	68.80	0.04	117.92	5545.44	1387.05	4.83	6937.32	6819.40
RATE>1.4	0.6	65.69	0.01	20.21	5294.37	1324.25	0.81	6619.42	6599.20

Figure 6

Costs and Benefits from Ridge Planting, Big Creek Targeting Based on Rate of Sediment Delivery

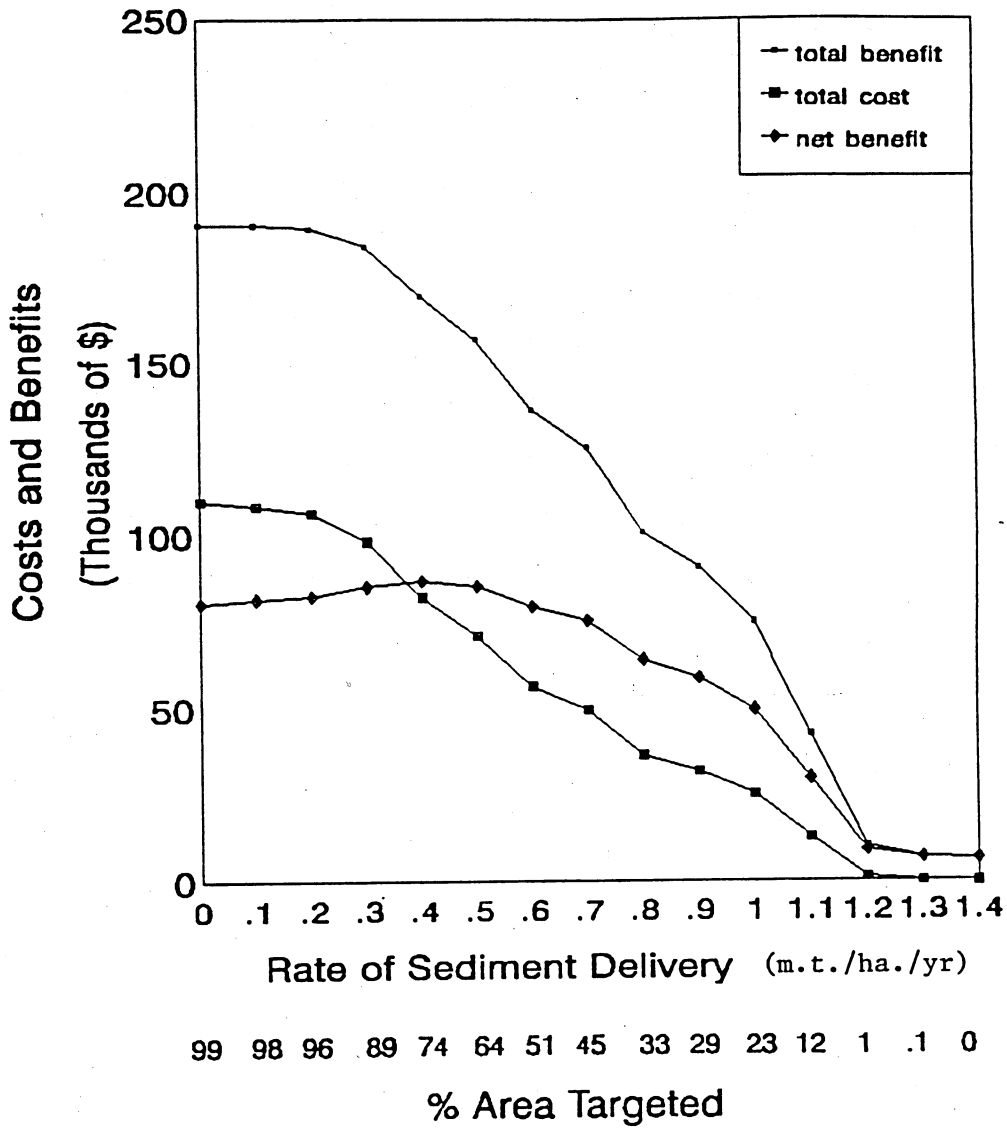


Table 9: Results from Targeting on Sediment Delivery Ratio, Big Creek

Conservation Measure CS/FCH

Sediment Delivery Ratio (%)	Area (Ha.) Targeted	Sediment Reduction (tons)	% Reduction in Erosion	Cost ($) of Adoption	Benefit ($) to Sport Fishing	Benefit ($) to Water Treatment	Benefit ($) to Water Conveyance	Total Benefit ($)	Net Benefit ($)
DR>0	3269.7	1312.11	43.59	54832.87	105756.31	26452.20	4903.59	137112.10	82279.23
DR>.1	3002.7	1281.37	39.95	50355.28	103278.33	25832.40	4494.90	133605.60	83250.35
DR>.2	1911.6	1015.64	23.79	32057.53	81860.71	20475.33	2675.87	105011.90	72954.38
DR>.3	1241.0	766.17	14.88	20811.57	61753.04	15445.92	1674.35	78873.31	58061.74
DR>.4	717.6	512.09	8.28	12034.15	41274.22	10323.68	931.59	52529.49	40495.33
DR>.5	273.8	245.41	2.99	4591.63	19780.19	4947.50	335.81	25063.49	20471.87
DR>.6	24.0	81.53	0.22	402.48	6571.56	1643.71	24.83	8240.10	7837.62
DR>.7	5.7	68.40	0.04	95.59	5512.69	1378.86	4.16	6895.71	6800.12
DR>.8	3.9	67.04	0.02	65.40	5403.53	1351.55	2.28	6757.36	6691.96
DR>.9	1.6	65.96	0.01	26.83	5316.20	1329.71	0.94	6646.85	6620.01
DR>1	1.0	65.42	0	16.77	5272.53	1318.79	0.40	6591.72	6574.95

Figure 7

Costs and Benefits from Fall Chisel Ploughing, Big Creek
Targeting Based on Sediment Delivery Ratio

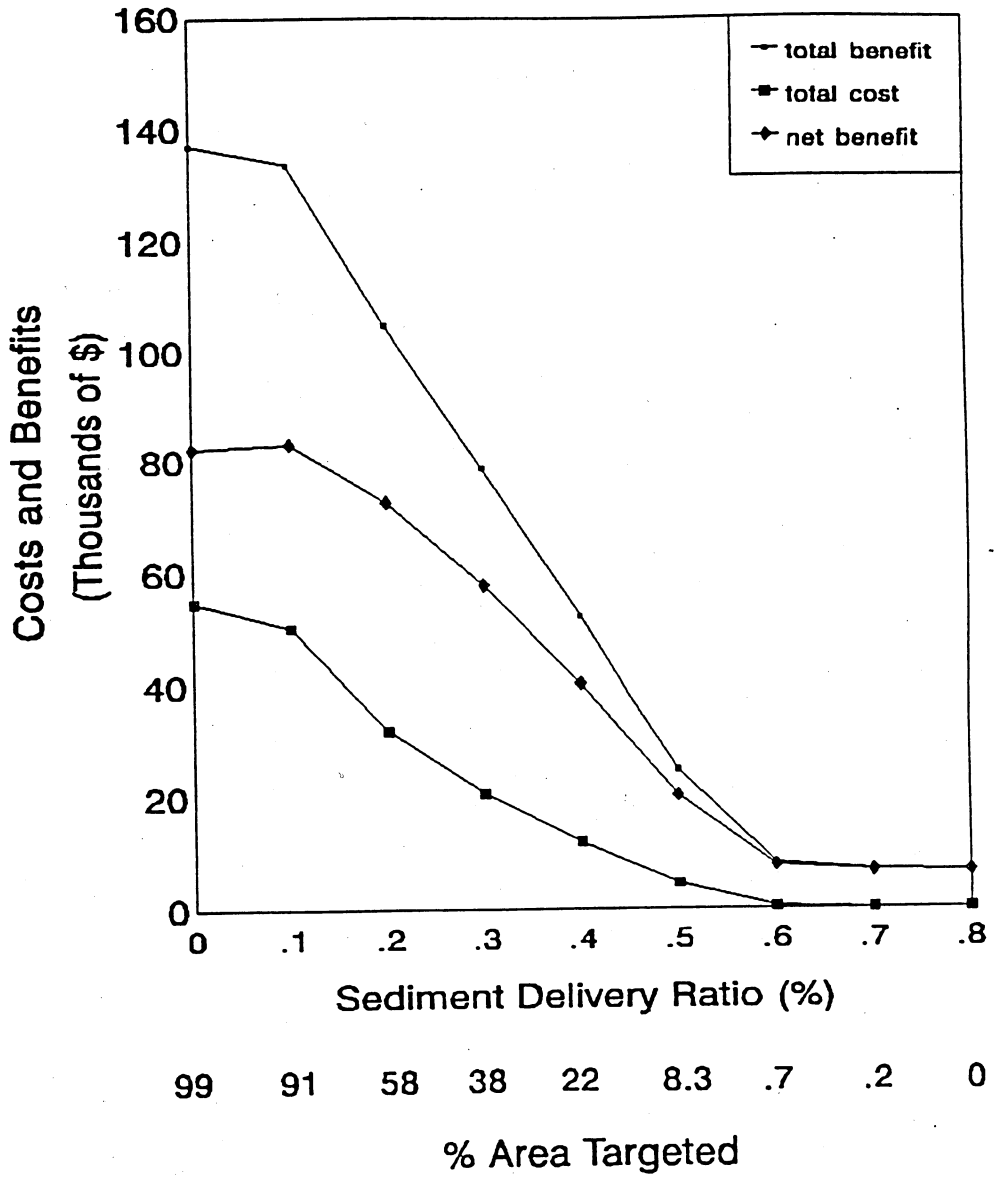


Table 10: Results from a Permanent Grass Buffer Zone, Big Creek

Distance to Stream (m.)	Area (Ha.) Targeted	Sediment Reduction (tons)	% Reduction in Erosion	Cost ($) of Adoption	Benefit ($) to Sport Fishing	Benefit ($) to Water Treatment	Benefit ($) to Water Conveyance	Total Benefit ($)	Net Benefit ($)
50	2.2	360.32	0.01	480.92	29041.61	7264.01	0.94	36306.56	35825.64
60	4.8	362.62	0.04	1049.28	29227.19	7310.42	4.56	36542.18	35492.90
70	8.2	365.87	0.11	1792.52	29489.18	7375.95	12.35	36877.48	35084.96
80	9.7	367.36	0.14	2120.42	29609.26	7405.99	15.97	37031.22	34910.80
90	22.0	384.02	0.41	4809.20	30951.95	7741.83	46.57	38740.35	33931.15
95	28.9	391.06	0.57	6317.54	31519.59	7883.81	64.16	39467.56	33150.02
100	33.7	393.91	0.68	7366.82	31748.84	7941.15	76.50	39766.49	32399.67
104	39.6	401.49	0.82	8656.56	32360.14	8094.05	91.94	40546.13	31889.57
105	42.0	405.42	0.87	9181.20	32676.71	8173.23	98.25	40948.19	31766.99
107	43.8	406.23	0.92	9574.68	32742.21	8189.62	103.08	41034.90	31460.22
110	51.9	415.03	1.10	11345.34	33451.77	8367.09	123.48	41942.34	30597.00
112	53.2	416.52	1.13	11629.52	33571.84	8397.13	126.97	42095.94	30466.42
114	54.9	419.23	1.17	12001.14	33790.17	8451.73	131.53	42373.43	30372.29
115	59.9	426.41	1.29	13094.14	34368.73	8596.45	145.09	43110.26	30016.12
116	65.4	435.08	1.42	14296.44	35067.37	8771.19	159.99	43998.54	29702.10
118	68.1	439.41	1.49	14886.66	35416.68	8858.57	167.37	44442.62	29555.96
120	73.9	448.49	1.63	16154.54	36148.07	9041.50	183.21	45372.78	29218.24
125	86.6	468.40	1.94	18930.76	37752.75	9442.87	218.10	47413.73	28482.97
130	109.5	501.85	2.51	23936.70	40449.06	10117.28	282.12	50848.47	26911.77
135	141.5	550.74	3.31	30931.90	44389.81	11102.96	372.85	55865.63	24933.73
140	169.8	593.68	4.03	37118.28	47850.26	11968.50	453.78	60272.54	23154.26
145	209.3	643.11	5.03	45752.98	51834.67	12965.10	565.86	65365.63	19612.65
150	279.2	717.33	6.75	61033.12	57816.76	14461.36	759.80	73037.92	12004.80
155	383.2	841.93	9.34	83767.52	67859.68	16973.34	1050.64	85883.67	2116.15
160	449.2	908.16	10.97	98195.12	73197.71	18308.51	1233.85	92740.07	-5455.05

Figure 8

COSTS AND BENEFITS FROM A PERMANENT GRASS BUFFER ZONE, BIG CREEK
TARGETING BASED ON DISTANCE TO THE STREAM

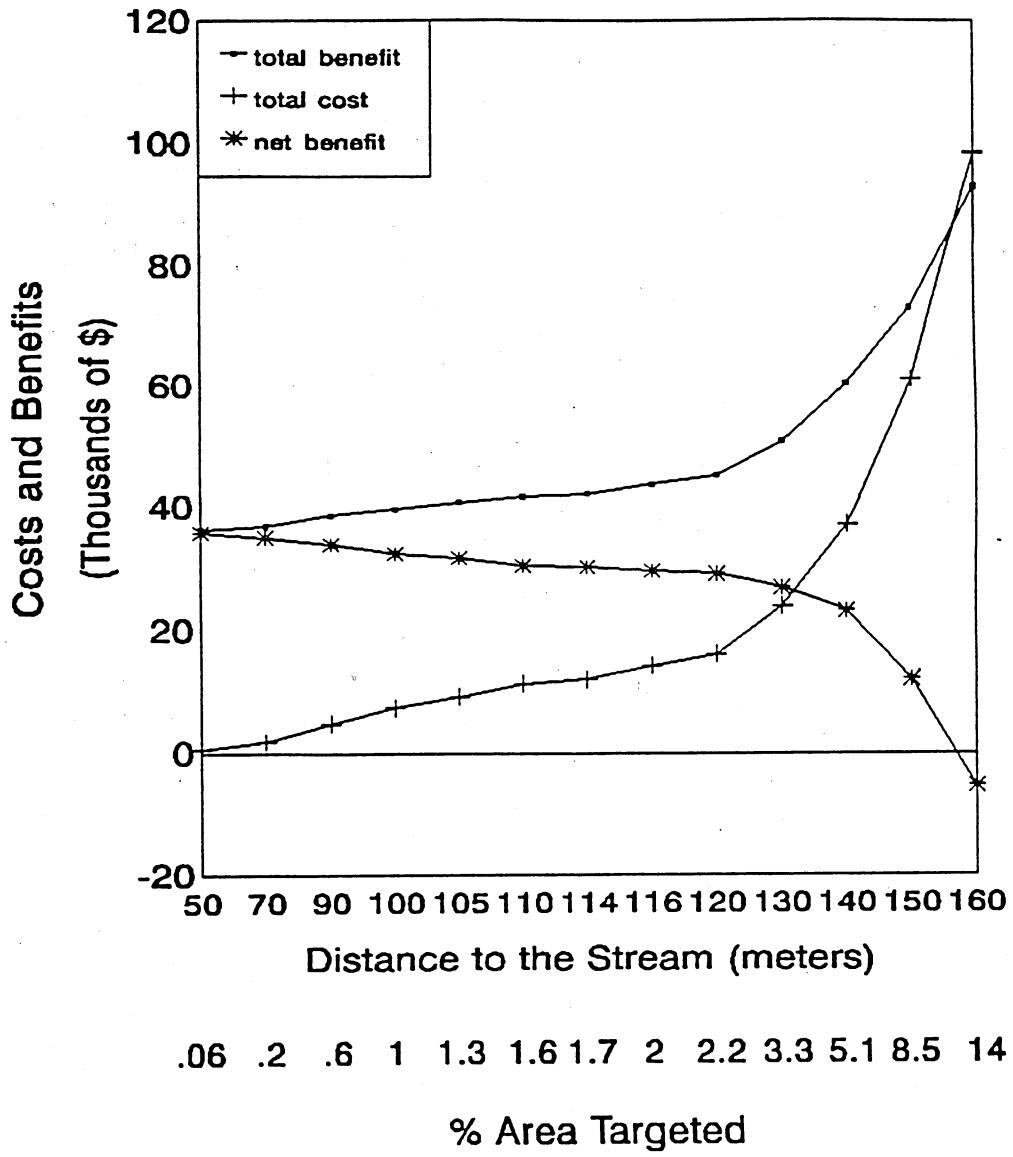


Table 11: Increased Benefit due to Targeting, Big Creek

Conservation Measure	Target Level	% Area Targeted	Net Benefits	
			Amount ($)	% Increase
CS/FCH	ALL	99	82279.23	-
	RATE ≥ .30	89	83514.80	1.5
	DR ≥ .10	91	83250.35	1.2
CS/RP	ALL	99	80723.06	_
	RATE ≥ .40	74	87483.90	8.4
	DR ≥ .10	91	84868.02	5.0
Permanent Grass	Distance ≤ 50	.06	35825.64	