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Soil Conservation Benefits of Sustainable Cropping Systems

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The conservation compliance provision of the Food Security Act (FSA) of 1985 requires farmers to control erosion on all highly erodible fields or lose their eligibility to participate in USDA farm programs. Since the income of farmers producing program crops is generally higher with than without farm programs, many farmers are expected to implement soil conservation plans that satisfy conservation compliance standards. Sustainable cropping systems can provide substantial soil conservation benefits and achieve conservation compliance. Unfortunately, most economic assessments of sustainable cropping systems do not quantify the soil conservation benefits. This paper evaluates the soil conservation benefits of sustainable cropping systems for an agricultural watershed.

Previous research

Economic and physical factors affecting the profitability and selection of alternative cropping systems have been examined at various scales. Factors examined at the farm level include: uncertainty in revenues and input supplies (Kramer, et al., 1983); crop yields, erosion and production costs (Klemme, 1985; Prato, 1984; Prato and Shi, 1989;Setia, 1987; Williams, 1988); soil loss control policies (Boggess, et al., 1979; Seitz, et al., 1979); and technological progress (Taylor and Young, 1985). Effects of alternative farming systems on erosion and/or nonpoint source pollution in an agricultural watershed have been evaluated by Frevert and Crowder (1987), Prato, et al. (1989), and Setia

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and Magleby (1988). Ribaudo (1986) established that there is substantial regional variation in offsite erosion damages. As social awareness of the potential environmental and health consequences of agricultural chemicals has increased, studies of cropping systems that reduce fertilizer and pesticide use have become more common (Dobbs, et al., 1988; Goldstein and Young, 1987; Helmers, et al., 1986). Unfortunately, most of these studies ignore the soil conservation benefits of sustainable cropping systems.

Study area

The study area is the Tom Beall watershed which is located in the lower end of Lapwai Creek drainage in northern Idaho. This watershed contains 8,785 acres of cropland and 2,605 acres of set-aside acreage and pasture. Due to the steepness of the land, high soil erodibility and the use of conventional tillage, 82 percent of the cropland in the watershed is eroding in excess of the soil loss tolerance or T value for the soils in this area, namely, 5 tons per acre per year (Shi, 1987). High erosion rates generate runoff which carries sediment and nutrients downstream where it impairs beneficial uses of water in Lapwai Creek, the Clearwater River and Lower Granite Reservoir.

Sustainable cropping systems

A sustainable cropping system is defined as one that maximizes net returns to farmers while achieving environmentally acceptable levels of erosion and sedimentation. Erosion is limited to the maximum field rates permitted by the conservation compliance provision for Idaho, namely, T, or in the case of economic hardship, 1.5T. Achieving these erosion limits is expected to reduce the volume of sediment leaving Tom Beall watershed.

A cropping system is a combination of tillage method, land treatment practice and crop rotation. Eight combinations of tillage method and land treatment practice are considered: CTUD = conventional tillage with up-and-down hill cultivation; CTCS = conventional tillage with cross slope farming; CTCF = conventional tillage with contour farming; CTDS = conventional tillage with divided slope farming; RTCS = reduced tillage with cross slope farming; RTCF = reduced tillage with contour farming; CRMCS = conservation tillage with crop residue management and cross slope farming; and CRMDS = conservation tillage with crop residue management and divided slope farming. Reduced tillage leaves about 30 percent residue cover and conservation tillage with residue management leaves between 50 and 65 percent residue cover after planting. CTUD and CTCS are dropped from the analysis because they have a higher erosion rate and a lower net return than CTCF. CRMCS is dropped because it has a higher erosion rate and lower net return than CRMCF.

Nine crop rotations are evaluated: WB = winter wheat-spring barley; WP = winter wheat-spring peas; WBP = winter wheat-spring barley-spring peas; WBF = winter wheat-spring barley-fallow; WPWF = winter wheat-spring peas-winter wheat-fallow; WPWFR = WPWF followed by rapeseed; WBWFR = winter wheat-spring barley-winter wheat-fallow-rapeseed; WPWPS = WPWP followed by four years of grass seed; and WBWBS = WBWB followed by four years of grass seed. A total of 29 cropping systems are evaluated: two baselines (CTCF and RTCF with a WP and WBP rotation); and CTDS, RTDS and

CRMDS with the nine crop rotations. For simplicity, the amount and location of pasture, hay and minor crops are held constant.

Methods

Baselines

Two baselines are specified. Baseline 1 represents the situation *before* conservation compliance went into effect. There is no income penalty for non-compliance in baseline 1. Baseline 2 represents the situation *after* conservation compliance went into effect. In baseline 2, net returns for farms not in compliance are calculated using market prices instead of target prices and total cropland acreage (no set aside acreage). Baselines 1 and 2 use two cropping systems on all fields in the watershed: the historical system (CTCF) and the cropping system that several farmers switched to during the 1987-88 period (RTCF). The cropping pattern for the two baseline systems is the one observed in the 1987-88 period, namely 70 percent of the cropland acreage is in a WP rotation and 30 percent is in a WBP rotation. Almost all cropland is ineligible for deficiency payments with the CTCF system and about 61 percent is ineligible with the RTCF system.

Erosion and sediment

Annual sheet and rill erosion rates for the 62 fields in the watershed are estimated using the Universal Soil Loss Equation or USLE (Wischmeier and Smith, 1978). Sediment delivery to the outlet of the watershed is estimated by multiplying total annual erosion by the sediment delivery ratio corresponding to a 10-year storm event, namely: 0.21 for the CTCF baseline, and 0.18 for the RTCF baseline and the two conservation compliance standards. Delivery ratios are estimated with the Agricultural Nonpoint Source Pollution (AGNPS) model (Young et al., 1987).

Onsite erosion damages are determined by multiplying the loss in yields due to erosion, as estimated with the Erosion Planning (EROPLAN) model (Dept. of Agr. and Res. Econ., 1978). EROPLAN calculates annual onsite damages by multiplying annual production losses due to soil erosion by crop prices. Production losses for all crops in the rotation equal crop yield times the percentage yield loss due to erosion. Yield losses are based on the following yield-topsoil depth relationship for winter wheat as estimated by Young and Taylor (1985): yield = 38.94+40.5*[1-0.9exp(topsoil soil depth)], where yield is in bushels per acre and topsoil depth is in inches. Topsoil depth is an inverse linear function of soil loss. This relationship implies that production losses increase at an increasing rate with respect to soil loss. In applying this relationship, EROPLAN assumes that the percentage yield loss corresponding to a given percentage decline in topsoil depth is the same for all crops. While the above relationship is estimated with data for the Palouse region, it is appropriate for Tom Beall watershed because it contains soil types similar to the Palouse. The importance of onsite erosion damages is evaluated using two criteria: the relative importance of onsite damages as measured by the ratio of total onsite damages to total cash returns and the selection of optimal cropping systems with and without onsite damages.

Offsite erosion damages due to sediment equal the total sediment delivered to the outlet of the watershed times the average damage per ton of sediment. Average sediment damages are equated to the annual benefit per ton of sediment reduction in Lower Granite Reservoir which McNamee et al. (1986) estimated to be $5.13 in 1984 dollars. The average sediment reduction benefit is $4.32 per ton of sediment after adjusting for inflation between 1984 and 1988 and the proportion of sediment trapped by Lower Granite Reservoir (McNamee et al., 1986).

The extent to which sediment damages affect the optimal choice of cropping systems is evaluated by comparing the privately and socially efficient levels of erosion control. If the same cropping system maximizes both annual cash returns and annual net returns (cash returns minus erosion damages) for the 62 fields in the watershed, then accounting for onsite erosion damages does not influence the optimal choice of cropping systems. Privately efficient erosion control maximizes total net returns to farmers which equal total cash returns to land, owner-operator labor and management, minus total onsite damages. Socially efficient erosion control maximizes net social value which equals total social net returns to land, owner-operator labor and management minus total sediment damages. Total social net returns equal social net returns per acre times the planted acreage in each field summed over all fields in the watershed. Social net returns are calculated using market rather than target prices. If the privately and socially efficient levels of erosion control are identical, then offsite sediment damages do not affect the optimal choice of cropping systems.

Annual net returns

Annual net returns to land, owner-operator labor and management are estimated for each cropping system and field using the EROPLAN model with a 20-year evaluation period (1988-2007) and a 4 percent real discount rate. Annual net returns equal gross returns minus the cost of chemicals, fertilizer, labor, fuel and seed, and machinery ownership costs, real estate depreciation and taxes minus annual onsite erosion damages. Annual returns were adjusted downward assuming a yield penalty (relative to conventional tillage) of 5 percent for reduced tillage and 15 percent for conservation tillage with residue management in the first year (1988) of the evaluation period (Hinman et al., 1983; Taylor, 1982). Yield penalties were reduced to zero at a linear rate during the first three years of the evaluation period (1988-90) to account for learning effects.

For fields having erosion rates less than or equal to 1.5T under both baselines and for all fields under the conservation compliance cases, annual cash returns and annual onsite damages are calculated using the following inflation-adjusted target prices for wheat and barley: $4.23/bu and $2.51/bu in 1988, $3.94/bu and $2.33/bu in 1989, and $3.68/bu and $2.16/bu in 1990, respectively. Target prices for wheat and barley are held constant at 1990 inflation-adjusted levels from 1991 to 2007. For fields not in compliance under baseline 2, annual net returns are calculated using inflation-adjusted market prices of $3.68/bu for wheat and $2.16/bu for barley. Prices of all other crops are assumed to remain constant, in inflation-adjusted terms, at their 1988 farm levels of $9/cwt for peas, $11/cwt for rapeseed and $100/cwt for grass seed.

Results

Optimal cropping systems

RTDS maximizes total annual net returns subject to the 1.5T and T erosion limits on all fields in the watershed. Half of the cropland is in a WP rotation and half is in a WPWPS rotation when erosion rates are limited to T. Seventy percent of the cropland is in a WP rotation and 30 percent is in a WPWPS rotation when erosion rates are limited to 1.5T.

Table 1 gives total cash returns, total onsite erosion damages and total net returns in 1988 for the baseline and compliance cases. Total values are calculated by multiplying the annual values by the corresponding planted acreage for each field and summing over all fields in the watershed. Baseline results indicate that total net returns are 24 percent lower with CTCF and 12 percent lower with RTCF after conservation compliance. This decline in net returns is caused by the loss in deficiency payments for farms not in compliance. Cropping systems that satisfy the T and 1.5T compliance standards boost net returns 45 to 49 percent relative to CTCF and 16 to 19 percent relative to RTCF when farmers are penalized for non-compliance. Income gains are lower with RTCF than with CTCF because RTCF is more profitable.

Net returns are higher for the conservation compliance cases than for the baseline systems for two reasons. First, the tillage system-land treatment practice in the optimal cropping system for the 1.5T and T cases (RTDS) has higher net returns per acre than CTCF or RTCF. Second, only one farm (less than 1 percent of the cropland) is in compliance with CTCF and five farms (33 percent of the cropland) are in compliance with RTCF. Farms not in compliance are ineligible to receive deficiency payments.

Erosion and sediment damages

Annual erosion decreases 70 percent with the T limit and 67 percent with the 1.5T limit relative to CTCF and 33 percent with the T limit and 25 percent with the 1.5T limit relative to RTCF. Total onsite erosion damages decrease 86 to 89 percent relative to CTCF and 49 to 59 percent relative to RTCF for baseline 2. Onsite damages are highest for the CTCF system and lowest for the T cases. The 1.5T cases give the second lowest onsite damages. Applying the two criteria for evaluating erosion damages indicates onsite erosion damages decrease in relative importance when less erosive systems are used and that onsite damages have very little effect on the optimal choice of cropping systems.

Table 2 gives annual sediment load, total sediment damages and net social value for the baseline and compliance cases. Mean sediment damages are 2.6 times greater for CTCF than for RTCF, 1.3 times greater for RTCF than for the 1.5T case and 1.5 times greater for RTCF than for the T case. Since the 1.5T case gives the highest net returns and net social value, the privately and socially optimal level of erosion control is 1.5T.

Policy Implications

Results of this analysis have several policy implications. First, onsite erosion damages and offsite (sediment) damages can be significantly reduced by using sustainable cropping systems that achieve conservation compliance. This suggests that onsite and offsite erosion benefits of conservation compliance may be substantial. Second, achievement of conservation compliance is likely to increase both net returns to farmers and net social value when deficiency payments are a large proportion of net returns to farmers. However, the incentive to adopt sustainable farming systems to achieve conservation compliance will decrease if acreage eligible for farm programs and/or target prices decline. For example, the triple base provision of the 1990 farm bill reduces this incentive by mandating a 15 percent reduction in the base acreage eligible for deficiency payments. Third, the farm income benefits of sustainable cropping systems may be a more important determinant of adoption than the soil conservation benefits especially in areas where erosion damages are low.

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Table 1. Total Cash Returns, Total Onsite Erosion Damages, Total Net Returns and Planted Acreage for Baselines and Conservation Compliance Cases, Tom Beall Watershed, 1988.

	Total cash returns	Total onsite erosion damages	Total net returns	Planted Acreage acres
Baseline 1				
CTCF	$491,087	$55,250	$435,838	6,595
RTCF	529,941	15,444	514,497	6,595
Baseline 2				
CTCF	373,928	59,013	314,914	7,686
RTCF	467,013	15,792	451,221	7,219
Conservation Compliance				
1.5T	556,141	8,208	547,933	6,832
T	543,960	6,384	537,576	6,832

Table 2. Annual Sediment Load, Annual Sediment Damages and Net Social Value, Tom Beall Watershed, 1988.

	Annual sediment yield (tons)	Total sediment damages	Net social value[b]
CTCF[a]	30,564	$132,036	$182,878
RTCF[a]	11,584	50,043	329,440
1.5T	8,643	37,337	398,518
T	7,726	33,376	397,695

a. For baseline 2
b. Total social net returns minus sediment damages.

Erosion, sediment, and economic effects of conservation compliance in an agricultural watershed

By Tony Prato and Shunxiang Wu

ABSTRACT: The erosion, sediment, and economic effects of achieving conservation compliance were determined for Idaho's Tom Beall watershed. Resource management systems were identified that maximize annualized net returns to land, labor, and management and limit erosion rates on all fields in the watershed to the standards established under conservation compliance—11.2 (T) and 16.8(1.5T) t/ha/yr. Three tillage systems, three land management practices, and nine crop rotations were evaluated. The universal soil loss equation was used to estimate annual erosion rates and the agricultural nonpoint-source pollution (AGNPS) model was used to estimate changes in sediment delivery to the outlet of the watershed for four storm events. Sediment delivery for individual storm events was aggregated to an annual basis using daily rainfall for a nearby weather station. Optimal resource management systems consist of reduced tillage with divided-slope farming and a wheat-pea or wheat-pea-wheat-pea-sod rotation. These resource management systems decreased total watershed erosion by 67% to 71% relative to conventional tillage with contour farming (CTCF) and by 25% to 33% relative to reduced tillage with contour farming (RTCF). Annual sediment delivery and sediment damages decreased 70% relative to CTCF and 23% relative to RTCF. Sediment damages were 2.5 times greater with CTCF than with RTCF. Total net returns increased 11% to 16% with respect to CTCF and decreased 1% to 4% relative to RTCF. Net social value was higher for the 1.5T standard than with the T standard. Achievement of the 1.5T conservation compliance standard is more efficient than achievement of the T standard.

THE focus of national conservation policy has shifted to include both on-site and off-site benefits of erosion control. The 1990 farm bill incorporates water quality criteria into the Conservation Reserve Program (CRP) and expands cross compliance to include best management practices for protecting water quality (*1*).

Support for these legislative initiatives is based on studies showing that the off-site benefits of reducing erosion exceed on-site benefits and that conservation compliance and the CRP may be inefficient in reducing off-site erosion damages (*7, 16, 19, 20*). Other studies indicate that erosion control practices designed to protect water quality (*13*) and that erosion control programs, such as the CRP, have water quality benefits (*16*).

Because of regional variation in on-site and off-site erosion damages (*15, 19*), the benefits of erosion and sediment control practices should be evaluated at the watershed level, which was the focus of our research.

Several studies have analyzed the effects of alternative agricultural management practices on erosion and/or nonpoint-source pollution (*4, 9, 12, 17*). Most of these studies ignored the yield losses from soil erosion. Soil, sediment, and nutrient losses associated with alternative conservation practices have been evaluated with the agricultural nonpoint-source pollution (AGNPS) model (*5, 14*). These studies did not consider off-site erosion damages. Braden and Johnson used the sediment economics (SEDEC) model to identify land management practices that minimized the cost of reducing sediment deposition in a small Illinois watershed (*2*). Conservation tillage was found to be the most profitable or cost-effective tillage method for reducing soil erosion on most Iowa soils (*12*), total soil erosion in Idaho's Tom Beall watershed (*14, 18*) and sediment/nutrient loadings to Illinois' Highland Silver Lake (*17*). This paper is based on the economic/resource assessment conducted by Wu (*25*).

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Study methods

Tom Beall watershed is located in the lower end of Lapwai Creek drainage in northern Idaho. The Soil Conservation Service (SCS) has determined that this drainage basin has serious erosion and water quality problems (*23*). The watershed contains 2,327 ha (5,745 acres) of cropland and 1,222 ha (3,017 acres) in set-aside acreage, pasture, and hay. This acreage is divided into 11 farms and 62 fields. Primary crops are winter wheat, spring barley, spring peas, and forage. Seventy-five percent of the cropland in the watershed is highly erodible because of the land's steepness and the soil types (*18*). Most soil erosion is caused by snowmelt runoff and winter rains in January and February and extensive use of conventional tillage. Runoff carries sediment and nutrients to Tom Beall Creek.

We used the following procedures to evaluate the erosion and sediment reduction benefits and economic impacts of achieving conservation compliance in Tom Beall watershed. First, we identified current and alternative resource management systems. We then estimated annual erosion rates and annualized net returns per hectare for all fields and resource management systems. Third, we compared resource management systems that maximized annualized net returns per hectare and satisfied Idaho's conservation compliance standards (optimal resource management systems) to those resource management systems currently used in the watershed. Last, we evaluated the erosion, sediment, and economic effects of the optimal resource management systems.

Resource management systems. A resource management system is a specific combination of tillage method, crop rotation, and land treatment practice. Conven-

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tional tillage with contour farming (CTCF) and a wheat-pea (WP) rotation or a wheat-barley-pea rotation (WBP) was the dominant resource management system in the 1986-1987 growing season. Casual observation during the 1987-1988 season indicated that some acreage was converted from CTCF to reduced tillage with contour farming (RTCF). Thus, we used CTCF and RTCF with a wheat-pea rotation or a wheat-barley-pea rotation as baselines. We evaluated seven alternative tillage-land treatment combinations: conventional tillage with up-and-down-hill cultivation (CTCS), conventional tillage with divided-slope farming[1] (CTDS), reduced tillage with cross-slope farming (RTCS), reduced tillage with divided-slope farming (RTDS), conservation tillage with crop residue management and cross-slope farming (CRMCS), and conservation tillage with crop residue management and divided-slope farming (CRMDS). Reduced tillage leaves about 30% residue cover, while conservation tillage with residue management leaves between 50% and 65% residue cover after planting.

We evaluated nine crop rotations: winter wheat-spring barley (WB), winter wheat-spring peas (WP), winter wheat-spring barley-spring peas (WBP), winter wheat-spring barley-fallow (WBF), winter wheat-spring peas-winter wheat-fallow (WPWF), WPWF followed by rapeseed (WPWFR), winter wheat-spring barley-winter wheat-fallow-rapeseed (WBWFR), WPWP followed by 4 years of grass seed (WPWPS), and WBWB followed by 4 years of grass seed (WBWBS). Resource management systems were selected with the assistance of SCS personnel. We assumed that the acreage in set-aside, pasture, and minor crops remained fixed in amount and location.

[1]Divided-slope farming divides the slope into an upper and lower segment containing different crops.

Erosion rates. Idaho's conservation compliance standards limit field-level erosion rates to either the soil loss tolerance (T) level of 11.2 Mg/ha/y (5 tons/acre/year) or 1.5T. While SCS prefers the T standard, the 1.5T standard is allowed if the T standard imposes an economic hardship on farmers.

We calculated soil erosion rates for each field using the universal soil loss equation (USLE) (*24*). We obtained the soil erodibility (K) and length-slope (LS) factors from soil and topographic maps and the rainfall (R) factor from meteorological sources (*11*). Tables 1 and 2 show the cover (C) factors for different rotations and tillage practices and the practice (P) factors for different slopes and rotations. Sheet and rill erosion rates and ephemeral gully erosion rates were summed to obtain total erosion rates for each field. We obtained C and P factors and ephemeral gully erosion rates from SCS.

Sediment yield. We used the AGNPS model (*26*) to estimate sediment yield at the outlet of the watershed for storm events having recurrence intervals of 10, 25, 50, and 100 years under the two baseline scenarios (CTCF and RTCF) and the two compliance standards. We derived sediment yield curves for each of the four cases by regressing estimated sediment yield for each storm event on the corresponding natural log of rainfall for that event. The coefficient of determination (R^2) for all regressions was 0.99. Daily sediment yield was predicted by substituting daily rainfall in the regression equations. Daily rainfall was for the Lewiston weather station, which is the closest weather station to Tom Beall watershed; data covered the 1947-1988 period. Sediment yield for each year was the sum of daily sediment yields.

Sediment control benefits. Sediment control benefits were set equal to the reduction in total sediment damages. We estimated the latter by multiplying the reduction in annual average sediment yields between each case and the baselines by the average damage per ton of sediment. McNamee estimated average damages per ton of sediment to be $5.65/Mg ($5.13/ton), in 1984 dollars, in Lower Granite Reservoir (*10*). This average damage consisted of $4.96/Mg, for naviagation and flood control, $0.24/Mg for municipal and industrial water treatment, and $0.45/Mg for the steelhead fishery. Adjusting for inflation between 1984 and 1988, the average damage per Mg of sediment delivered to Lower Granite Reservoir was $5.76/Mg ($5.23/ton). Lower Granite Dam traps about 75% of the sediment entering Lower Granite Reservoir (*10*); thus, average damage per Mg of sediment equals $4.76/Mg ($6.34×0.75), in 1988 dollars.

Net returns. We estimated annualized net returns per hectare to land, owner-operator labor, and management for each resource management system and field using the erosion planning (EROPLAN) model (*3*), with a 20-year evaluation period (1988-2008) and a 4% real discount rate. EROPLAN automatically annualizes net returns per hectare downward to account for the on-site productivity damages (yield losses) from soil erosion. An additional downward adjustment was made in annualized net returns to reflect the declining target prices mandated by the Food Security Act of 1985 and the lower yields observed with reduced tillage (RT) and conservation tillage with residue management (CTRM) than with conventional tillage. First-year yield penalties were 5% with RT and 15% with CTRM (*6, 21, 22*). Because yield penalties are expected to decrease as farmers become more familiar with alternative tillage systems, yield penalties were reduced to zero by the third year (1990) of the evaluation period.

We used inflation-adjusted target prices for wheat and barley in the first 3 years of the simulation period (1988-1990): $.15/kg ($4.23/bushel) and $.11/kg ($2.51/bushel) in 1988, $.014/kg (3.54/bushel) and $0.10/kg ($2.33/bushel) in 1989, and $0.13/kg ($3.68/bushel) and $0.09/kg ($2.16/bushel) in 1990, respectively. There is considerable uncertainty regarding crop prices in the 1991-2007 period. Target prices for wheat and barley are established by farm legislation, and

Table 1. C factors for alternative resource management systems, Tom Beall watershed.

	C Factors by Tillage System		
Rotation*	Conventional Tillage	Reduced Tillage	Conservation Tillage with Residue Management
W-P	0.42	0.22	0.10
W-B	0.34	0.18	0.07
W-B-P	0.37	0.15	0.09
W-P-W-F	0.38	0.20	0.10
W-P-W-F	0.48	0.18	0.12
W-P-W-F-R	0.29	0.14	0.125
W-B-W-F-R	0.24	0.14	0.11
W-P-W-P-S	0.29	0.15	0.06
W-B-W-B-S	0.25	0.13	0.05

*W, wheat; P, peas; B, barley; F, fallow; R, rapeseed; S, sod.

Table 2. P factors for alternative resource management systems, Tom Beall watershed.

	P Factors by Crop Rotation			
Slope (%)	Cross-Slope and Contour Farming	Without Sod Divided-Slope Farming	Cross-Slope and Contour Farming	With Sod Divided-Slope Farming
1-2	0.75	0.60	0.45	0.30
3-5	0.65	0.50	0.40	0.25
6-8	0.65	0.50	0.40	0.25
9-12	0.75	0.60	0.45	0.30
13-16	0.85	0.70	0.55	0.35
17-20	0.90	0.80	0.60	0.40
21-25	0.95	0.90	0.65	0.45
>25	0.95	0.95	0.70	0.50

*P factor for up-and-down-hill farming is 1.0.

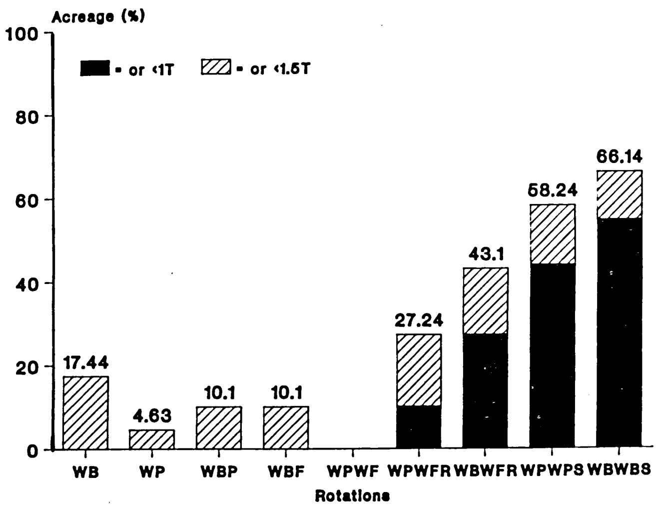

Figure 1. Acreage satisfying conservation compliance standards with CTCF baseline, Tom Beall watershed.

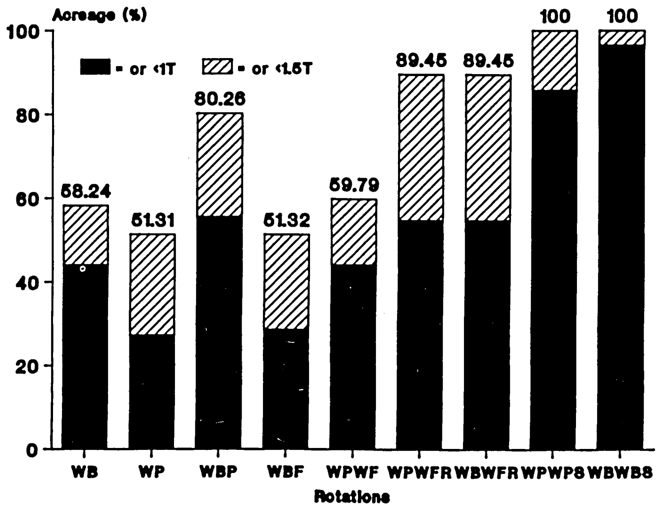

Figure 2. Acreage satisfying conservation compliance standards with RTCF baseline, Tom Beall watershed.

market prices for peas, rapeseed, and grass seed (sod) are determined by demand and supply conditions. One alternative for dealing with price uncertainty is to evaluate net returns for each resource management system using different price assumptions. Because five crops are included in the resource management system, there would be a large number of price combinations to consider with this approach. Furthermore, there is little basis for choosing among price combinations. In addition, unless relative prices for the five crops change, varying absolute prices will not affect the economic ranking of resource management systems. Therefore, we assumed that target prices for wheat and barley would remain constant at their 1990 inflation-adjusted levels from 1991 to 2007 and farm prices of all other crops would be constant at their 1988 inflation-adjusted levels of $0.19/kg ($9/hundredweight) for peas, $0.24/kg ($11/hundredweight) for rapeseed, and $0.20/kg ($100/hundredweight) for grass seed. To permit comparison of net returns to farmers before and after conservation compliance, we included deficiency payments for wheat and barley in baseline net returns.

Results

The number of fields and total acreage satisfying the conservation compliance standards increased when reduced or conservation tillage methods replaced conventional tillage and/or when rapeseed or grass seed was included in the rotation. Between 5% and 17% of the acreage satisfied the 1.5T standard with the CTCF baseline and a more erodible crop rotation (WB, WP, WBP, WBF, or WPWF) (Figure 1). Between 10% and 55% of the total acreage satisfied the T standard and 27% to 66% satisfied the 1.5T standard with the CTCF baseline and a less erodible rotation. For the RTCF baseline, 10% to 55% of the acreage satisfied the T standard and 51% to 80% satisfied the 1.5T standard with an erodible crop rotation (Figure 2). Between 44% and 97% of the acreage satisfied the T standard and between 89% and 100% satisfied the 1.5T standard with the RTCF baseline when rapeseed or grass seed was included in the rotation. Average soil erosion was 32.5 Mg/ha/y (2.9T) for the CTCF baseline and 13.4 Mg/ha/y (1.2T) for the RTCF baseline.

For all fields, reduced tillage with divided-slope farming and either a WP or WPWPS rotation maximized annualized net returns per hectare subject to the field-level erosion limits. Half of the cropland in the watershed was in the WP rotation and half in the WPWPS rotation for the T standard; 70% wasi n the WP rotation and 30% in the WPWPS rotation for the 1.5T standard (Table 3). Changes in annual erosion and net returns to farmers varied with the compliance standard and the baseline (Table 4). Annual erosion decreased 71% with the T standard and 67% with the 1.5T standard relative to the CTCF baseline and 33% with the T standard and 25% with the 1.5T standard compared to the RTCF baseline. Total annual returns (without cost-sharing) increased 11% with the T standard and 16% with the 1.5T standard with the CTCF baseline, but decreased 4% for the T standard and 0.65% for the 1.5T standard relative to the RTCF baseline. While optimal resource management systems and annual erosion were not affected by cost-sharing for conservation practices, net returns were about 4% higher with cost-sharing than without.

Table 3. Optimal crop acreage for alternative conservation compliance standards, Tom Beall watershed.

Optimal Resource Management System		*Conservation Compliance Standard**			
		T		*1.5T*	
Tillage and Land Treatment†	*Rotation‡*	*Area (ha)*	*Percent*	*Area (ha)*	*Percent*
RTDS	WP	1,175	50.40	1,621	69.68
RTDS	WPWPS	1,152	49.50	706	30.32

*Excludes set-aside acreage and pasture.
†RTDS, reduced tillage with divided-slope farming.
‡WP, winter wheat-spring peas; WPWPS, wheat-peas-wheat-peas, followed by 4 years of grass seed.

Table 4. Soil erosion and net returns with alternative conservation compliance standards, Tom Beall watershed.

Baseline/ Conservation Compliance Standard*	*Soil Erosion*		*Net Returns*		*Average Efficiency‡ ($/ton)*
	Total (Mg)	*Percent Change†*	*Total ($)*	*Percent Change†*	
CTCF	132,009	-	406,476	-	-
1.5T	43,549	−67.01	470,372	15.72	−0.72
T	38,932	−70.51	452,880	11.42	−0.50
RTCF	58,370	-	473,458	-	-
1.5T	43,549	−25.39	470,372	−0.65	0.21
T	38,929	−33.31	452,880	−4.35	1.06

*CTCF, conventional tillage with contour farming; RTCF, reduced tillage with contour farming.
†Relative to baseline.
‡Change in net returns divided by change in total erosion relative to baseline.

Table 4 also shows the average efficiency of erosion reduction, or the change in net returns (without cost-sharing payments) divided by the reduction in annual erosion relative to the baselines. A negative (positive) average efficiency indicates that net returns increase (decrease) with respect to erosion reduction. Achieving conservation compliance was efficient relative to the CTCF baseline but inefficient relative to the RTCF baseline. This is significant because some farmers in the watershed already have shifted from CTCF to RTCF. The 1.5T standard was more efficient than the T standard.

Table 5 shows estimated annual sediment load, total sediment damages, and net social value. For both standards, sediment reduction loads and damages were about 70% less relative to the CTCF baseline and 23% less relative to the RTCF baseline. Total sediment damages were 2.5 times greater for the CTCF baseline than for the RTCF baseline, 1.3 times greater for the RTCF baseline than for the 1.5T standard, and about the same for the 1.5T and T standards.

The net social value (Table 5) equals total net returns to farmers (without cost-sharing) minus deficiency payments minus total sediment damages and, for the T and 1.5T standards, the public cost of the conservation compliance program. We excluded deficiency payments from the net social value because they are a transfer payment to farmers. The public cost of achieving conservation compliance in Tom Beall watershed was estimated to be $19,743 in 1988 dollars. We derived this cost by multiplying average federal expenditures on erosion reduction under the Conservation Technical Assistance Program [$8.37/ha ($3.39/acre) in 1988 dollars] by the amount of highly erodible cropland [2,359 ha (5,830 acres)] in the watershed. Because the net social value is higher for the 1.5T standard than for the T standard, it is more efficient, from a social viewpoint, to reduce erosion rates to 1.5T rather than to T.

Table 5. Annual sediment yield, annual sediment damages, and net social value, Tom Beall watershed.

Standard*	Annual Sediment Yield (Mg)	Total Sediment Damages† ($)	Net Social Value‡ ($)
CTCF‡	3,239	15,418	42,968
RTCF	1,282	6,102	361,543
1.5T	999	4,755	452,722
T	988	4,702	449,490

*CTCF, conventional tillage with contour farming; RTCF, reduced tillage with contour farming.

†Annual average damage is $4.76/Mg of sediment.

‡Total net returns (from Table 4) minus deficiency payments, minus total annual sediment damages, minus (for 1.5T and T only) the public cost of conservtion compliance.

Net returns, adjusted for on-site erosion damages, were 16% higher with the 1.5T standard and 11% higher with the T standard relative to the CTCF baseline, but decreased for both standards relative to the RTCF baseline. Net social value was highest for the 1.5T standard, followed by the T standard, RTCF baseline, and CTCF baseline.

Conclusions

Conservation compliance required farmers to reduce erosion rates to T or 1.5T on all highly erodible fields in the Tom Beall watershed. Using resource management systems that maximized net returns to farmers subject to conservation compliance decreased total erosion by 67% to 71% relative to the CTCF baseline and 25% to 33% relative to the RTCF baseline. Total erosion was 12% higher with the 1.5T standard than with the T standard. Average sediment yield and sediment damages decreased 70% relative to the CTCF baseline, 23% relative to the RTCF baseline, and were almost identical for the T and 1.5T standards.

In summary, achieving conservation compliance in Tom Beall watershed would generate significant erosion and sediment reduction benefits. Compared to pre-compliance levels, net returns to farmers and net social values were higher relative to the CTCF baseline but lower relative to the RTCF baseline. If farmers in Tom Beall watershed continue to replace conventional tillage with reduced tillage, the economic incentive to be in compliance will decrease. However, as long as net returns to farmers are higher with deficiency payments than without, farmers would be expected to opt for compliance. Finally, the 1.5T conservation compliance standard is preferable to the T standard from the viewpoint of farmers and society.

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