Bulletin No. 655

An Evaluation of Best Management Practices On Dryland Farms in the Upper Snake River Basin of Southeastern Idaho:

Fremont, Madison, Teton, Bonneville, Caribou and Franklin Counties

M. L. Powell and E. L. Michalson

Agricultural Experiment Station

University of Idaho

College of Agriculture

Contents

Summary 3
Introduction 4
Study Objectives 4
Methodology 5
Study Area 5
Data Sources 6
Evaluation of BMPs 6
Continuous Cropping 6, Crop Residue Management 6, Terracing 7, Field Strip Cropping 7, Grass Waterways 8
Impacts of the BMPs on Farm Income: Analysis by Farm Size 9
Model Assumptions 10
Results: Small Farm Size 11
Results: Large Farm Size 12
Conclusions 13
Literature Cited 15
Appendix A: Input Costs by Farm Size 16

About the Authors

Marie L. Powell is a former research associate, and Edgar L. Michalson is professor of agricultural economics, both in the Department of Agricultural Economics, University of Idaho, Moscow.

Published and distributed by the
Idaho Agricultural Experiment Station
Gary A. Lee, Director
University of Idaho College of Agriculture
Moscow, Idaho 83843

500; July 1986

$1.00 per copy

Summary

The research reported here is concerned with evaluating Best Management Practices (BMPs) to control soil erosion in the Upper Snake River Basin of southeastern Idaho. Dry cropland accounts for more than half of all productive ground in the Upper Basin, upwards of 700,000 acres. Historical crop production has been achieved at the expense of relatively high rates of soil erosion deemed as excessive on as much as 44 percent of the dry cropland in the Snake River Basin. Surface runoff from heavy rain and snowmelt is the primary cause of soil erosion.

The predominance of a wheat-fallow cropping system in the Basin has contributed to the severity of erosion as well since the fallowed ground is left vulnerable at critical erosion periods. Soil loss averages 8 tons per acre annually in the Basin. The potential for significant yield decreases exists unless erosion is reduced.

This publication has analyzed the effects of implementing measures to control soil erosion on a representative small and large sized dryland farm in the higher precipitation zone of the Upper Snake River Basin. The practices considered included continuous cropping, crop residue management, terracing, strip cropping and grass waterways.

These BMPs were all effective in reducing soil erosion. Applying the BMPs at their maximum levels caused an average reduction in soil loss of 55 percent for the two farms studied. Soil losses average 4.5 tons per acre when no soil erosion control measures were used on the farms. A soil loss of about 2 tons per acre was achieved with implementation of the entire package of BMPs.

Implementation of all the BMPs except continuous cropping represented a cost to the farm operator. Elimination of summer fallow from the crop rotation contributed an average of $24 per acre to net farm revenue for the two farms studied. Of the other BMPs, crop residue management had the lowest average cost per acre followed by strip cropping, terracing and grass waterways.

Continuous cropping actually contributed to net farm income and was adopted for the farms before soil loss was constrained.

For the small sized farm, strip cropping was the most economical practice when soil loss was limited, followed by terracing. Strip cropping was also identified as the most economical practice on the large sized farm, followed by crop residue management and terracing. As terracing yields were assumed to increase in the models, terracing was steadily substituted for the other practices as the more economical alternative. At a yield benefit of 7.5 to 8 percent, installation of terracing caused an increase in net income on the farms.

The impact on farm income of adopting the most erosion resistant package of BMPs was a reduction of 15 percent to net farm revenues. This impact would be reduced somewhat if terracing was accompanied by an increased yield on the terraced portion of the field. Alternatively, net returns would be reduced by another 17 percent if continuous cropping was not available to insulate farm income from the costs of the other BMPs. To put it another way: net returns for farms that cannot use continuous cropping as a BMP would be reduced by 17 percent regardless of whether they adopted terracing or any other BMP. This occurs because of the loss of productivity related to reduced cropping acreage.

An Evaluation of Best Management Practices On Dryland Farms in the Upper Snake River Basin of Southeastern Idaho:

Fremont, Madison, Teton, Bonneville, Caribou and Franklin Counties

M. L. Powell and E. L. Michalson

Introduction

The research reported here is concerned with evaluating Best Management Practices (BMPs) to control soil erosion in the Upper Snake River Basin of southeastern Idaho. Dry cropland accounts for more than half of all productive ground in the Upper Basin, upwards of 700,000 acres. Historical production has been achieved at the expense of relatively high rates of soil erosion deemed as excessive on as much as 44 percent of the dry cropland in the Snake River Basin (USDA 1979). Surface runoff from heavy rain and snowmelt is the primary cause of soil erosion. The predominance of a wheat-fallow cropping system in the Basin has contributed to the severity of erosion as well since the fallowed ground is left vulnerable at critical erosion periods.

Persistent erosion of topsoil has been linked to reductions in crop yield response. Research indicates that an inch of soil lost to erosion decreases yield from 3 bushels per acre on soils 24 inches deep to 8 to 10 bushels per acre on soils 12 inches deep (Walker and Young 1982). With soil losses averaging 8 tons per acre annually in the Basin, the potential for significant yield decreases appears to exist unless erosion is reduced. This publication evaluates several methods proposed to control soil erosion in the Upper Snake River Basin.

Study Objectives

The purpose of this study is to examine the economic effectiveness of selected BMPs to reduce soil erosion in the Upper Snake River Basin of southeastern Idaho. Specific objectives included:

1. Estimate costs and soil loss values for the BMPs in the study region.
2. Analyze the economic impact of adopting the BMPs for two representative farm sizes in the Upper Basin under alternative cropping schemes.
3. Evaluate the effectiveness of BMPs in reducing soil loss for each model farm.

The following BMPs were examined:

1. **Continuous Cropping:** This practice provides crop cover for the farm fields each year. Continuous cropping has been shown to be an effective way to reduce soil erosion in the area.
2. **Crop Residue Management:** This practice should be applied each year. It includes leaving stubble standing over the winter, stubble mulching during the spring and summer and maintaining at least 1,500 pounds of residue cover per acre at planting time. It also includes planting all crops on the contour.
3. **Terracing:** It involves the installation of level terraces on long slopes ranging from 4 to 12 percent with the objective of breaking the length of the slopes. Spacing between terraces is determined by slope. These terraces are designed to intercept and hold runoff from the field area above the terraces.
4. **Field Strip Cropping:** This BMP is designed to provide alternate strips of crops and summer fallow across fields that have long slopes. The alternate pattern of crops provides erosion protection by working as a filter to slow down the water as it moves down slope.
5. **Grass Waterways:** Permanent vegetative plantings are used to reduce erosion. Seeding grass in waterways provides the soil with adequate protection from erosion, while at the same time providing cover for wildlife and other environmental amenities.

Continuous cropping was evaluated by eliminating fallow from the rotation. Crop residue management was evaluated using the minimum tillage practices assumed for the farm. Terracing was evaluated in terms of the costs of installing and maintaining terraces and the additional operating costs of farming with terraces over an assumed 10-year life. Strip cropping was evaluated through the added operating costs associated with this BMP. Grass waterways were evaluated in terms of the installation costs for the waterway and the reduced income caused by substituting grass for regularly cropped acreage. The overall goal of the analysis was to determine the short run effect of these BMPs on farm income. All investment costs were evaluated on an annual basis.

Methodology

Three different techniques were used here. They are linear programming, enterprise budgeting and field tillage simulation.

A linear programming (LP) procedure was used to estimate the effects on farm income of implementing erosion control measures. The LP models determined profit maximizing production levels for a small and large farm given a choice of crop rotations, tillage systems and BMPs and a series of soil loss restrictions. The results of the models were compared to assess the impact on net returns to fixed factors of production for each farm size.

Enterprise budgeting was used to calculate baseline production costs and returns for small grain crops in the Upper Basin. The budgets, developed through the Idaho Enterprise Budget Generator, estimated the variable costs of production for conventional and minimum tillage practices. The Budget Generator program estimated variable machinery and labor costs for specified tillage operations on each farm.

A Field Tillage Simulation (FTS) program (Miller 1979) was used to analyze the added farming costs of terracing and strip cropping. The Field Tillage Simulator model is a computer program that has been developed cooperatively between the departments of Agricultural Economics and Agricultural Engineering at the University of Idaho. The FTS program accepts the outline of a specific field as input and graphically simulates tillage operations with any equipment package the user selects. Field coordinates in the program can be adjusted to incorporate conservation practices such as terracing and strip cropping. The costs of farming with these BMPs were derived using information provided by the FTS program.

Study Area

The study area for this publication is the Upper Snake River Basin comprised of the dry croplands adjacent to the intermountain border of Idaho and Wyoming. This zone — including Fremont, Madison, Teton, Bonneville, Caribou and Franklin counties — receives 16 inches or more of annual precipitation and experiences extreme winter temperatures. A map delineating the study area is shown in Fig. 1.

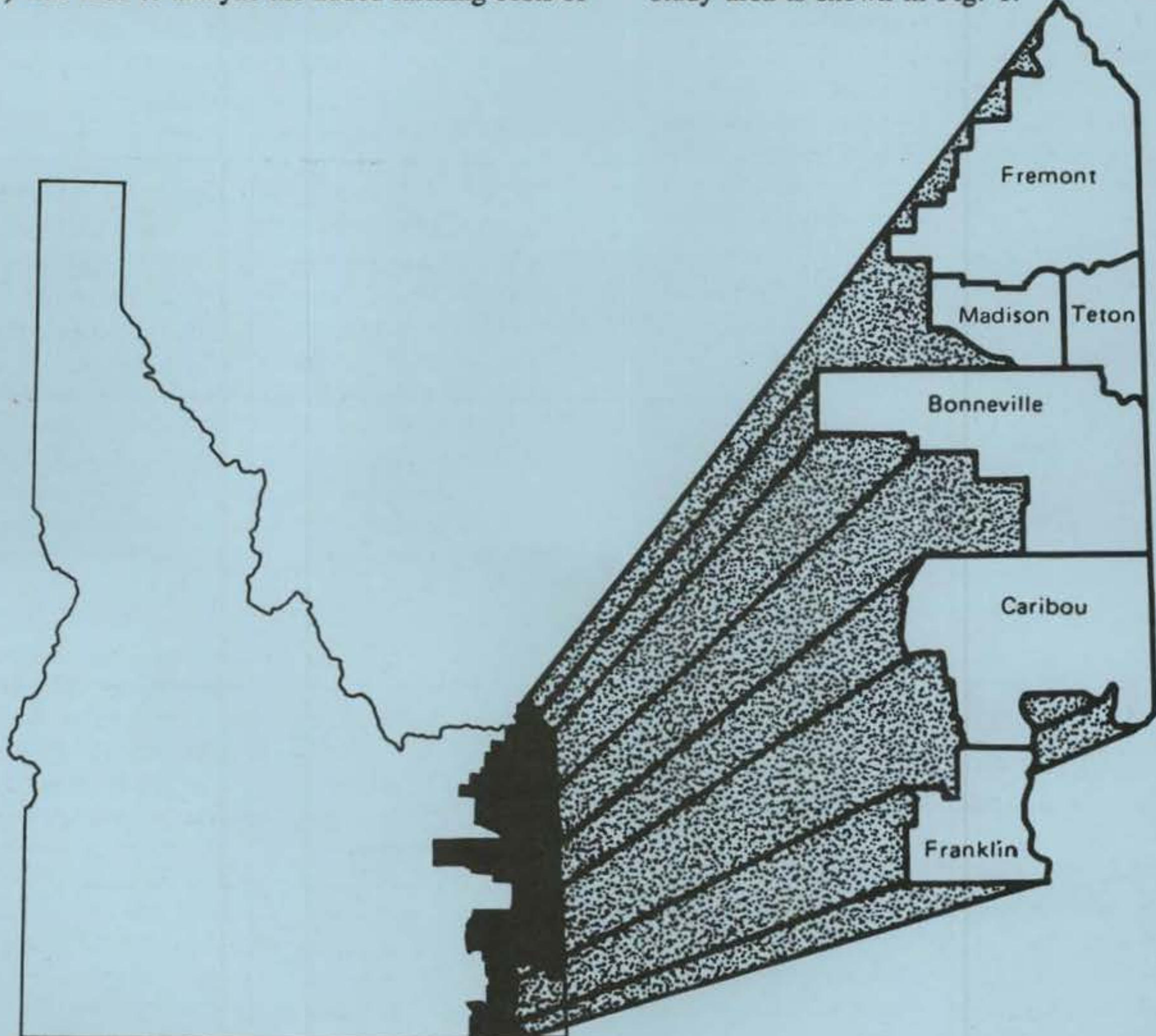

Fig. 1. Study area.

Small grain crops typify dryland production in this region. Grain production is predominantly winter wheat and spring barley, although spring wheat is produced in smaller proportion. Crop rotations generally include a period of summer fallow preceding the planting of winter wheat followed by a spring barley or a spring wheat crop.

Data Sources

Data used in this study were obtained from a variety of sources. Basic data were provided by a farm survey performed in the Snake River Basin in 1979. Ninety-five farmers were interviewed in the survey, and a detailed farm schedule was obtained from each. Information was provided on farm sizes, rotations, machinery complements, tillage systems and conservation practices of the region. This data were updated to represent 1982 prices for inputs, machinery and revenue items.

Other important sources of data included the Soil Conservation Service (SCS) offices in Boise, Pocatello and Idaho Falls, Idaho. Information detailing the physical and biological aspects of the BMPs was provided by these offices along with cost estimations for some items. Soil loss calculations were based on D. K. McCool's et al. (1981) modification of the Universal Soil Loss Equation. Southeastern Idaho farm chemical and equipment dealers provided 1982 cost data for the study as did the district 4 agricultural extension economist for the University of Idaho. Other professionals in the College of Agriculture at the University of Idaho also provided information.

Evaluation of the BMPs

This section describes the BMPs and presents the average costs associated with each in the Upper Basin. The averages are drawn from specific data developed for the representative small and large sized farms used in this publication. Appendix A contains input costs for each farm.

Continuous Cropping — This refers to the elimination of summer fallow from the rotation. Summer fallow is used to store moisture in the soil and control weed problems. After the fallow period is over, the land is planted to winter wheat. In a continuously cropped rotation, wheat would be planted immediately after the previous crop.

Summer fallow contributes to erosion because the ground is bare of cover during critical erosive periods. However, the practice is necessary in dryland areas where annual precipitation is insufficient to support continuous crop production. Research has shown that summer fallow is required when annual precipitation is less than 16 inches or when weed infestations are severe (McDole and Shiray 1980).

Continuous cropping in the Upper Basin was assumed to cause a 10 percent reduction in winter wheat yields from those obtained after summer fallow. Although yields may be reduced somewhat, the land no longer sits idle for a full crop year. Instead, the ground is contributing net revenue to the farm. A comparison between a continuous winter wheat crop and a winter wheat-fallow crop illustrate the situation.

Income above variable costs for a continuous winter wheat crop averaged $65.60 per acre for the two farms studied. The income above variable costs for both years of a winter wheat-fallow rotation was $83.48. The average yearly return for this crop was $41.74 per acre ($83.48/2), clearly less than the annual crop. The success of annual cropping presumes the continued presence of sufficient moisture to sustain crop growth year after year and the absence of severe weed problems.

Crop Residue Management — This entails preserving a certain amount of residue on top and below the soil surface to help hold the soil in place during critical erosion periods. The distribution of organic matter in and on the soil acts to improve the water holding capacity and structure of the soil.

Crop residue management is achieved by reducing the number of tillage practices used to prepare the ground for planting, thereby minimizing the breakdown of residue. Conventional tillage incorporates 80 to 100 percent of residue into the soil, while minimum tillage preserves at least 50 percent of crop residue on the surface (Michalson 1983). Table 1 presents typical conventional and minimum tillage practices in the study area.

The yield differences attributable to minimum vs. conventional tillage are not well documented. Where soil moisture is limiting, the increased moisture reten-

Table 1. Minimum/conventional tillage combinations in the Upper Snake River Basin.

Crop	Tillage intensity	Chisel plow	Chisel w/sweeps	Disk or field cultivator	Rod-weeder	Double harrow
		Times over				
Winter wheat - fallow	conventional	1		2	3	
	minimum	1	1		2	
Winter wheat annual	conventional	1		2		
	minimum	1	1			
Spring barley	conventional	1		1	1	1
	minimum	1	1		1	

tion capacity of the soil generated by minimum tillage tends to contribute to crop yields. If soil moisture is not limited, the increased water retention tends to have a negative effect on yields.

For purposes of this study, no change in crop yield was assumed with minimum tillage. As Table 1 shows, very little change in field operations takes place from conventional to minimum till in this region. Application of an additional 20 pounds of fertilizer was assumed with minimum tillage to compensate for the slower decomposition of organic matter under residue management. Table 2 indicates the effect on cost of crop residue management for a winter wheat-fallow crop, a continuous winter wheat crop and a spring barley crop.

Terracing — This is a common BMP used in southeastern Idaho. A terrace is an earth embankment or ridge built across a slope. Its purpose is to reduce runoff and soil erosion by breaking up the slope length of a field. Terracing also adds to soil moisture by allowing runoff to remain on the field to be absorbed into the soil. Preliminary experiences with terracing indicate that the additional moisture may have a positive effect on yields within the terraced field; however, the exact effect on yield response has not yet been fully quantified.

Terracing is recommended by the SCS on slope classes from 4 to 12 percent. The SCS office in Idaho Falls, Idaho, provided construction cost estimates used in this publication. Maps of terraced fields in southeastern Idaho were also obtained from the SCS. Economic evaluation of terracing is comprised of two elements: the costs of building the terrace and the additional operating cost of farming a terraced field.

The construction cost of terraces in the Upper Basin was \$0.48 per lineal foot of terracing, assuming use of a sophisticated terracing machine to construct the terrace. The length, spacing and number of terraces in a field depends on many factors including slope length and steepness, soil type and farming practices. An average figure of 75 feet of terrace per acre was selected to represent terrace length and spacing based on sample terraced fields. Initial construction costs were estimated as \$36 per acre of installed terrace (\$0.48 ×75 feet = \$36.00). Maintenance costs of 10 percent of installation were expected costs that were to be incurred during the fifth year of the terrace life. The resulting installation and maintenance costs were \$39.60 per acre.

To address the time differential between costs and benefits and the substantial investment required by terracing, a 10 year declining balance payment schedule was applied to the principal cost of implementing terracing. The average annual costs per acre for terraces consisted of an annual payment of \$6.71 to cover the annual equivalent costs of building the terrace program allows a comparison between a field farmed as a whole and the same field as farmed when terraces are included. Figs. 2 and 3 illustrate the FTS representation of a field with and without terraces. Inputs to the program consist of coordinate points defining the field and implement data detailing such factors as implement width, speed, draft, and fuel and holding capacities where applicable.

The critical information provided by the program is the elapsed time required to farm the field before and after terracing. Using a representative set of implements for the Basin, a 12 percent increase in operating time was projected for terracing. This percentage was used to increase the following variable costs of production from the enterprise budgets including fuel, oil, lube and repair costs for tractors, combines and implements. Labor costs were also increased. Performing operations between terraces necessitates increased applications of seed, fertilizer and herbicide because of problems of overlap and turning. These input costs were increased by 10 percent.

Table 3 presents the additional operating costs of farming between terraces for a winter wheat-fallow crop, a continuous winter wheat crop and a spring barley crop.

Field Strip Cropping — This is a BMP used to reduce erosion on long, steep slopes. The slope is divided into sections and planted so that a portion is always in plant cover. Alternating strips of crops with high and low erosion protection provides for greater soil stability during peak erosion months, slows runoff velocity and allows greater absorption of water into the soil. In southeastern Idaho, the SCS recommends strip cropping on slope classes greater than 12 percent. Maps of strip cropped fields used in this study were obtained from the SCS. The costs of strip cropping were

Table 2. Effect on cost per acre of crop residue management in the Upper Snake River Basin.

Crop	Savings in fuel, oil, lube and repair costs/acre[1]	Added labor costs/acre[2]	Added fertilizer costs/acre[3]	Net added cost of crop residue management
Winter wheat - fallow[4]	-\$0.08 (-\$0.16)	\$0.04 (\$0.08)	\$2.10 (\$4.20)	\$2.22 (\$4.44)
Winter wheat - annual	\$0.05	\$0.09	\$4.20	\$4.24
Spring barley	\$0.03	\$0.00	\$4.20	\$4.17

[1]Savings are for the various implements listed in Table 1 including the tractor.

[2]Added labor costs are caused by switching from a larger, faster disk to a smaller sweep chisel.

[3]Assuming an additional 20 pounds of fertilizer per cropped acre for minimum till.

[4]Figures are presented for a single year. To include both years, see numbers in parentheses.

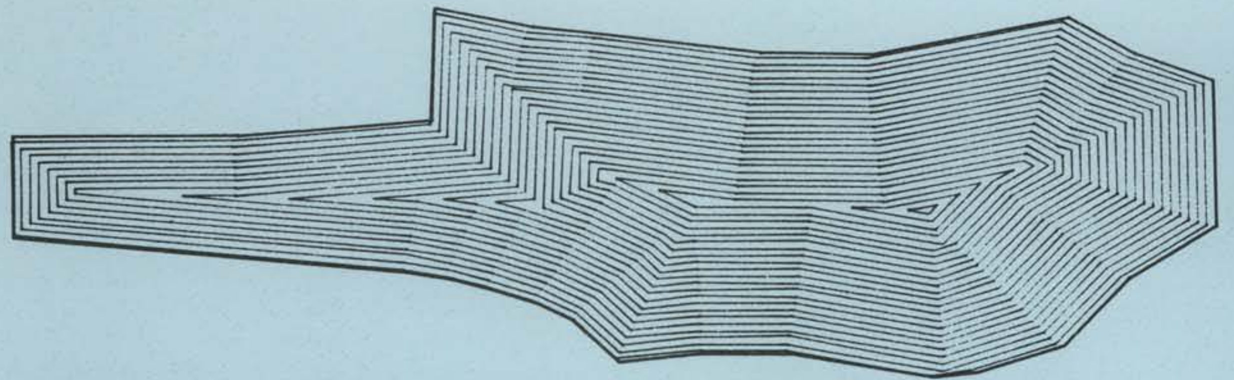

Fig. 2. An example of a conventionally farmed field as produced by the Field Tillage Simulator Model.

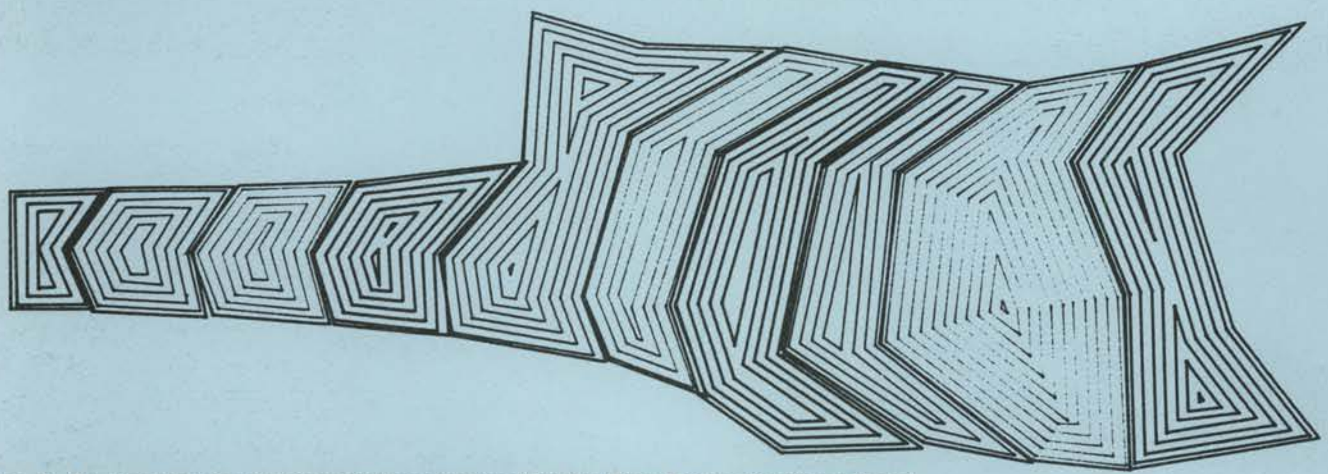

Fig. 3. An example of a terraced field as produced by the Field Tillage Simulator Model.

calculated from the FTS program and enterprise budgeting. The FTS program facilitates comparisons between field operations performed before and after the installation of strips. Information about the field and the equipment package is input to the program, and the FTS returns a graphic display of farming operations on the field. Figs. 4 and 5 show the FTS display from a conventionally farmed field and strip cropped field.

Higher costs of strip cropping result from the additional operating time required in the field. The FTS indicated that, for a representative set of implements used in the Basin, strip cropping required an 8.46 percent increase in operating time. This increase was directly related to problems of overlap and the fact that more machine time is tied up in making more turns to farm individual strips.

Relevant variable costs were increased to reflect added machine time in the field. Fuel, oil, lube and repair costs for the tractors, combines and implements were increased by 8.46 percent. Labor, seed, fertilizer and herbicide material costs were increased by 10 percent. Table 4 summarizes operating costs of farming strip cropped fields for a winter wheat-fallow crop, a continuous winter wheat crop and a spring barley crop.

Grass Waterways — These are an effective BMP for controlling waterborne sediment. The waterway is planted to erosion resistant grasses that provide a permanent cover to trap sediment. The waterway channel directs surface water away from unprotected cropland and acts as a filter for sediment carried in runoff, thereby improving water quality in the area.

Table 3. Additional operating costs of farming with terraces in the Upper Snake River Basin.

Crop	Added fuel, oil, lube and repair costs/acre[1]	Added labor costs/acre	Added herbicide fertilizer and seed costs/acre	Net added operating cost/acre of terracing
Winter wheat - fallow[2]	$1.65 ($3.30)	$0.59 ($1.18)	$0.81 ($1.62)	$3.05 ($6.10)
Winter wheat annual	$3.04	$0.82	$2.16	$6.02
Spring barley	$3.30	$0.88	$1.86	$6.04

[1]Includes tractors, implements and combines.

[2]Costs are presented for a single year. To convert costs to include both years, see numbers in parentheses.

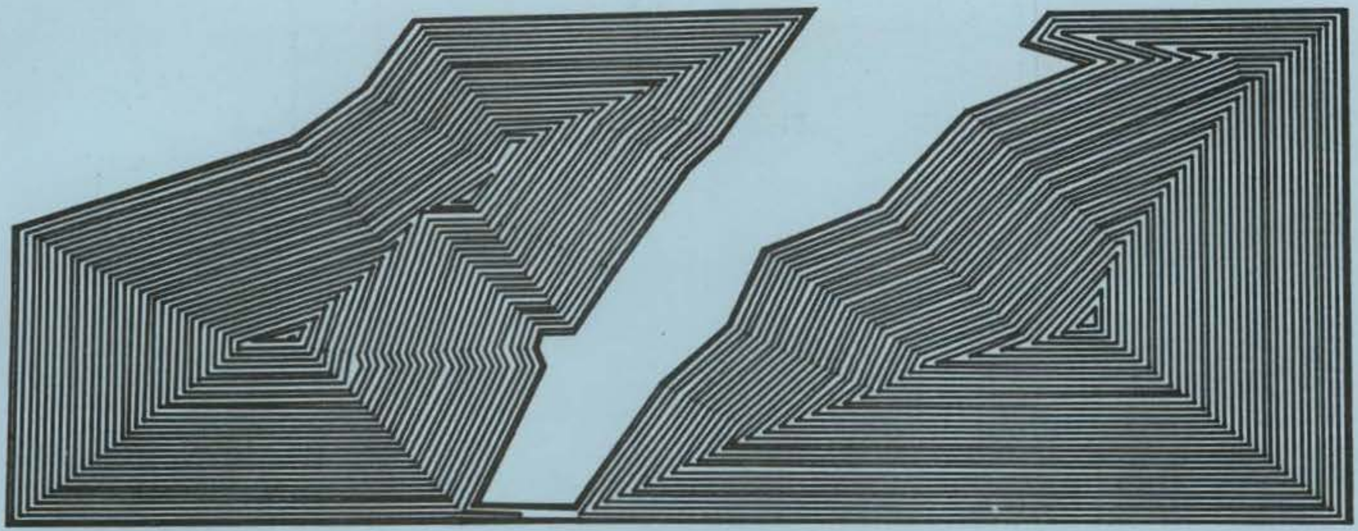

Fig. 4. An example of a conventionally farmed field as produced by the Field Tillage Simulator Model.

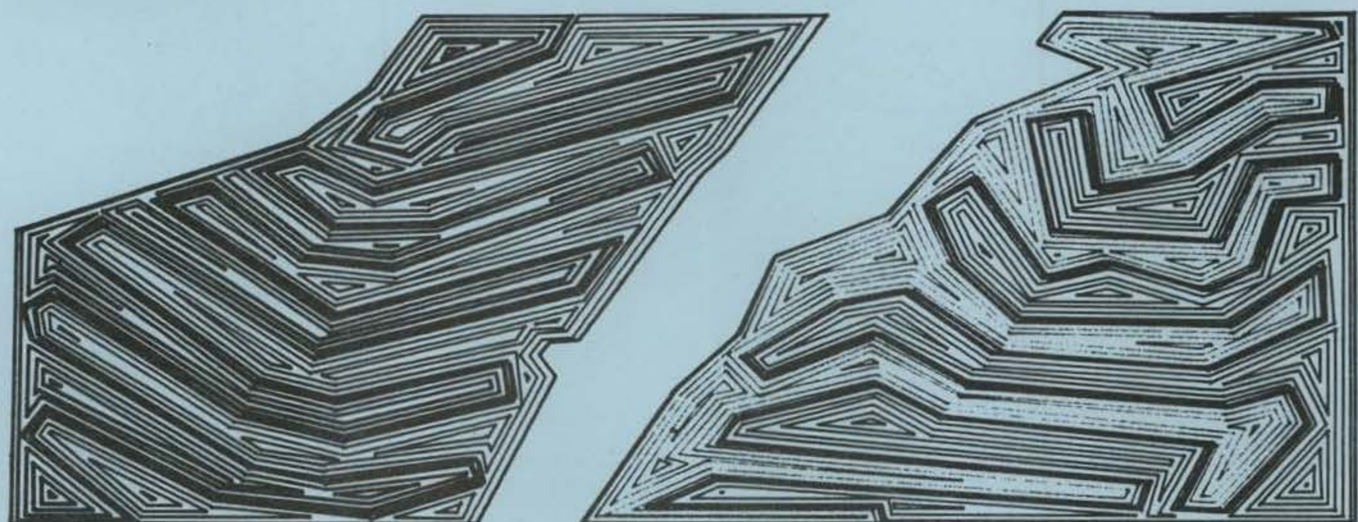

Fig. 5. An example of a strip cropping field as produced by the Field Tillage Simulator Model.

Farm safety may also be enhanced by properly constructed waterways, since the formation of gullies and ditches is prevented.

Cost estimates of constructing grass waterways were provided by the SCS. The cost of designing, shaping, sloping and seeding a waterway averaged $1,000 per acre. Like terracing, grass waterway construction costs occur immediately while the benefits in terms of reduced sedimentation are experienced over the useful 10-year life of the waterway. Annual costs of this BMP were estimated using a 10-year declining balance payment schedule on the investment principal. Assuming an interest rate of 14 percent, the annual cost to the farm operator for installing a grass waterway was $186.36 per acre.

Impacts of the BMPs On Farm Income: Analysis by Farm Size

Profit maximizing linear programming models were used to analyze the impacts of the BMPs on farm in-

Table 4. Additional operating costs of farming with strip cropping in the Upper Snake River Basin.

Crop	Added fuel, oil, lube and repair costs/acre[1]	Added labor costs/acre	Added herbicides, fertilizer and seed costs/acre	Net added operating cost/acre of strip cropping
Winter wheat - fallow[2]	$1.14 ($2.28)	$0.59 ($1.18)	$0.81 ($1.62)	$2.54 ($5.08)
Winter wheat annual	$2.12	$0.82	$2.16	$5.10
Spring barley	$4.57	$0.88	$1.86	$5.03

[1]Includes tractors, implements and combines.

[2]Costs are presented for a single year. To convert costs to include both years, see numbers in parentheses.

come. Models representing small and large sized farming operations in the Upper Snake River Basin were developed. The mathematical representation of the LP model is:

$$\text{Maximize } Z = C_1X_1 + \ldots + C_jX_j$$

$$\text{Subject to: } D_k \geq \sum_{j=1}^{j} A_{jk}X_j$$

Where: Z = net income to fixed factors of production

C_j = net revenue per acre of the jth production activity

X_j = acreage level of the jth production activity

D_k = total amount of the kth resource available

A_{jk} = total input of the kth resource required by the jth production activity

The solution to the LP model provides information on the most economic production decisions given the activities and constraints of the model. Profit maximizing rotations are identified and the most cost effective BMPs for a specified level of soil loss are revealed.

Model Assumptions — Activities in the models included various crop rotations and the BMPs under consideration. The crop rotations included:

1. Winter wheat (50 percent) — spring barley (50 percent).
2. Winter wheat (50 percent) — fallow (50 percent).
3. Winter wheat (25 percent) — fallow (25 percent) — spring barley (50 percent).
4. Winter wheat (33 percent) — spring barley (33 percent) — fallow (33 percent).

The impact of the BMPs on farm income is directly related to the level at which the practice is adopted on the farm. The models were constrained to allow a maximum of 41 percent of the farm to be treated by terracing, 33 percent to be treated by field strip cropping and 1 percent to be diverted to grass waterways. Crop residue management was unconstrained, i.e. minimum tillage was permitted on up to 100 percent of the farm acreage. These constraint levels were derived from SCS standards of suitability by slope class of the BMPs and from estimates of slope class distributions in the study area. Soil loss values for the models were calculated using the Universal Soil Loss Equation (USLE).

Four LP models were developed to analyze the BMP packages used in this study. The first model (model I, Tables 5 and 7) was unrestricted in terms of the amount of erosion (soil loss) that could occur. In models II, III and IV, soil loss was progressively restricted. The maximum soil loss per acre permitted on the small size farm (700 acres) was 3.14 tons per acre; for model III,

Table 5. Impact of BMPs on net farm income, soil loss and rotation on a representative 700-acre farm in the Upper Snake River Basin.

BMP scenarios	Original program:	Terracing programs:		
Models	No yield increase for terracing	2.5% yield increase for terracing	5% yield increase for terracing	10% yield increase for terracing
I. Unrestricted model				
Net farm income	$46,470	$46,470	$46,470	$47,280
Soil loss	2,555	2,555	2,555	2,080
(tons/acre)	(3.65)	(3.65)	(3.65)	(2.97)
Rotation[1]	W-B	W-B	W-B	W-B
BMPs[2]	None	None	None	Terraces
II. Level one constraints				
Net farm income	$45,665	$45,665	$45,705	$47,280
Soil loss	2,200	2,200	2,200	2,080
(tons/acre)	(3.14)	(3.14)	(3.14)	(2.97)
Rotation	W-B	W-B	W-B	W-B
BMPs	Strip crop	Strip crop	Terraces	Terraces
III. Level two constraints				
Net farm income	$43,344	$43,956	$44,585	$46,419
Soil loss	1,700	1,700	1,700	1,700
(tons/acre)	(2.43)	(2.43)	(2.43)	(2.43)
Rotation	W-B	same	W-B	W-B
BMPs	Strip crop Terraces	Strip crop Terraces	Terraces Strip crop	Terraces Strip crop
IV. Level three constraints				
Net farm income	$39,100	$40,017	$40,934	$42,768
Soil loss	1,451	1,451	1,451	1,451
(tons/acre)	(2.07)	(2.07)	(2.07)	(2.07)
Rotation	W-B	W-B	W-B	W-B
BMPs	Min. till Terraces Strip crop G. water	Min. till Terraces Strip crop G. water	Min. till Terraces Strip crop G. water	Min. till Terraces Strip crop G. water

1Crop rotation: W-B = winter wheat (50 percent) — spring barley (50 percent).

2BMPs: Min. till = minimum tillage; strip crop = strip cropping; terraces = terracing, G. water = grass waterways.

it was 2.43 tons per acre, and for model IV, 2.07 tons per acre. On the larger size farm (2,200 acres), the soil loss constraints were: (1) model II, 3.41 tons per acre; (2) model III, 2.73 tons per acre; and (3) model IV, 2.13 tons per acre.

The first LP runs analyzed the effects of implementing all BMPs on net farm income. This series began with an unrestricted model in which no BMPs were required to enter the solution. In succeeding runs, lower and lower levels of soil loss were mandated until finally all the BMPs were included in the solution at their maximum levels. The second series of runs analyzed situations of increased yields for terraced acres, with particular emphasis on the corresponding effect on BMP selection and farm income. Yield increases of 2 1/2, 5 and 10 percent were projected in the models. Subsequent runs identified the break-even yield required to induce terracing into the solution. Finally, continuous cropping was eliminated as a rotation to examine the effects on production decisions when this BMP was not available.

Results: Small Farm Size

A farm of 700 acres was used to represent small sized dryland operations in the region. Yields of 36 bushels for annual winter wheat, 40 bushels for winter wheat after fallow, 48 bushels for spring barley and 1 ton per acre for any cut grass were assumed. Prices of $3.50 per bushel of wheat, $2.70 per bushel of barley (equivalent to $112.50 per ton) and $50 per ton of grass were used. Soil loss was initially unrestricted at a level of 3.65 tons per acre on the farm.

All four (I, II, III, IV) LP models identified the continuous winter wheat-spring barley rotation as the most profitable at all levels of soil loss constraints. Sustain-

Table 6. Effects of varying yield response associated with terracing on a representative 700-acre farm with unconstrained soil loss, model I farm.

	6% yield increase for terracing	7% yield increase for terracing	7.5% yield increase for terracing	8% yield increase for terracing
Net farm income	$46,470	$46,470	$46,470	$46,547
Soil loss (tons/acre)	3.65	3.65	3.65	2.97
Other BMPs[1]	None	None	None	Terraces
Rotation[2]	W-B	W-B	W-B	W-B

[1]No other BMPs were included under this scenario.

[2]Rotation: W-B = winter wheat (50 percent) — spring barley (50 percent).

Table 7. Impact of BMPs on net farm income, soil loss and rotation on a 700-acre farm without continuous cropping.

BMP scenarios Models	Original program: No yield increase for terracing	Terracing program: 10% yield increase for terracing
I. Unrestricted model		
Net farm income	$38,661	$39,137
Soil loss	3,045	2,510
(tons/acre)	(4.35)	(3.59)
Rotation[1]	W-F&B	W-F&B
BMPs[2]	None	Terraces
II. Level one constraints		
Net farm income	$38,589	$39,137
Soil loss	3,000	2,510
(tons/acre)	(4.28)	(3.59)
Rotation	W-F&B	W-F&B
BMPs	Strip crop	Terraces
III. Level two constraints		
Net farm income	$37,785	$39,122
Soil loss	2,500	2,500
(tons/acre)	(3.57)	(3.57)
Rotation	W-F&B	W-F&B
BMPs	Strip crop	Terraces
IV. Level three constraints		
Net farm income	$31,222	$34,057
Soil loss	1,876	1,876
(tons/acre)	(2.68)	(2.68)
Rotation	W-F&B	W-F&B
BMPs	Min. till Terraces Strip crop G. water	Min. Till Terraces Strip crop G. water

[1]Rotation: W-F&B — winter wheat (25 percent) — fallow (25 percent) — spring barley (50 percent).

[2]BMPs: Min. till = minimum tillage; terraces = terracing; strip crop = strip cropping; G. water = grass waterways.

ing dryland yields with this rotation is dependent on receiving 16 inches or more precipitation each year.

Field strip cropping was selected as the most economical BMP satisfying initial soil loss constraints in models II, III and IV. At a constraint level of 3.14 tons of soil loss per acre, 22 percent of the farm was placed under strip cropping. When soil loss was constrained to 2.43 tons per acre, strip cropping increased to 33 percent, the maximum level allowed, and terracing was prescribed for 27 percent of the farm. The final constraint level of 2.07 tons of soil loss per acre caused all the BMPs to enter the solution at their maximum levels in model IV. Crop residue management was selected for 100 percent of the farm, strip cropping for 33 percent, terracing for 41 percent and grass waterways for 1 percent. Soil loss was reduced from the original 3.65 tons per acre to 2.07 tons per acre, a 43 percent reduction.

LP models summarized the impact of the BMPs on farm income. Net farm income at first decreased by 2 percent with the entry of strip cropping (models II, III and IV). When strip cropping was increased and terracing introduced at the next constraint level, net farm income decreased by another 5 percent. Full implementation of the entire set of BMPs caused a 16 percent reduction in net farm income from the original level.

Preliminary unpublished results of research on terracing done at Pendleton, Oregon, indicates that in low rainfall areas, 18 inches and less rainfall, terracing induces a yield response of up to 10 percent of yields on non-terraced ground.[1] The main effect appears to be that of increasing soil moisture over the growing season. Level terraces are designed to hold water on the fields and permit it to infiltrate into the soil profile. This increased soil moisture is thought to be the source of these increased yields. Additional research data to substantiate these preliminary findings is currently underway.

In addition to the above research, SCS personnel located at Malad, Idaho, in Oneida County have made field observations that support the conclusions of the research at Pendleton.[2] These field observations tend to fall into the 2½ to 10 percent yield increase range. The programming results developed in this analysis used the above range to allow for variation in rainfall, soils and managerial factors.

The models with increases in yields for terraced acres revealed terracing as the most economical conservation practice when accompanied by a 5 percent or greater increase in yield. With a 5 percent yield increase on terraced acres, terracing was substituted for strip cropping as the more economical practice satisfying soil loss constraints. The impact on net farm income of adopting BMPs was softened when terracing contributed to revenue through increased yields.

[1]Paul Rassmussen and Clyde Douglas, unpublished research on terracing in eastern Oregon. USDA/ARS, Pendleton, OR.

[2]John Grub, conservationist, SCS office, Malad, ID.

When terracing induced a 10 percent increase in yields, it entered the solution at its maximum level even before soil loss was constrained. In this model, soil loss was immediately reduced to 2.97 tons per acre, and net farm income was initially 2 percent higher than the original level. Further analysis revealed that a yield increase of 8 percent was required before terracing automatically entered the solution. At this point, net income on the small farm was increased by installing terracing.

Table 5 presents the results of the LP analysis for the small farm model when a continuous cropping rotation was available. Net farm income, soil losses, BMPs and profit maximizing rotations are outlined for each model in the series. Table 6 shows the net farm income and soil losses associated with terracing under various yield assumptions for an unconstrained level of soil loss.

Table 7 summarizes the production decisions for the small farm when all rotations include a fallow period. Notice that net farm income was lower and soil loss higher when a wheat-fallow crop was substituted for continuously cropped winter wheat in the rotation. The BMP selection was consistent with the earlier results.

Results: Large Farm Size

A 2,200-acre farm represented large sized dryland operations in the study area. Yields of 36 bushels for annual winter wheat, 40 bushels for winter wheat after fallow, 48 bushels for spring barley and 1 ton per acre of harvested grass from grass waterways were assumed. Prices of $3.50 per bushel of wheat, $2.70 per bushel of barley and $50 per ton of grass were used in the models. Soil loss for the farm was originally unconstrained at 3.95 tons per acre.

The continuous, winter wheat-spring barley rotation was again identified as the most profitable at all levels of soil loss constraint. When continuous cropping was not available, a wheat-fallow and spring barley rotation was substituted as the most profitable of the fallow rotations. This rotation contained the least percentage of fallow.

Field strip cropping was initially identified as the most economical BMP satisfying soil loss restraints for the large sized farm. A soil loss constraint of 3.41 tons per acre caused 22 percent of the farm to be placed under strip cropping. The next constraint level of 2.73 tons per acre increased strip cropping to its maximum of 33 percent and introduced terracing on 10 percent of the farm and crop residue management on 57 percent. The final constraint of 2.13 tons of soil loss per acre induced all the BMPs into the solution at their maximum levels. Crop residue management was specified for 100 percent of the farm, strip cropping for 33 percent, terracing for 41 percent and grass waterways for 1 percent of the farm. Soil loss was reduced 46 percent from the original level by inclusion of the full set of BMPs.

The impact on farm income accompanying the application of the BMPs was outlined by the LP runs. Entry of the first BMP, strip cropping, caused a 2 percent reduction in net farm income. The increased application of strip cropping, terracing and crop residue management in the second set of BMPs resulted in a decrease of 5 percent. Adoption of the final package of BMPs, all at their maximum, caused net farm income to drop by 14 percent from the original level.

The effect on terracing of 2 1/2, 5 and 10 percent yield increases for terraced acres was evident immediately on the large sized farm. With a yield increase of 2 1/2 percent, terracing was substituted for minimum tillage as a more economical practice to satisfy the second level of soil loss constraint. A yield increase of 5 percent caused terracing to be substituted for strip cropping at the outset as the most economical conservation practice. The impact on net farm income accompanying adoption of the BMPs was lessened proportionally as terracing contributed revenue to the farm through increased yields.

A yield benefit of 10 percent for terracing caused terracing to enter the solution even though soil loss was unrestrained. The immediate introduction of terracing on the farm caused soil loss to decrease to 3.24 tons per acre while farm income rose 2 percent above the original level. Further scrutiny of terracing yields identified 7.5 percent as the yield increase required to voluntarily introduce terracing into the solution on the large farm. At this yield benefit, net farm income was increased by installing terraces.

The results of the LP analysis for the large sized farm are provided in Table 8. Net farm income and soil losses are presented for four farm models (I, II, III and IV), and profit maximizing rotations and BMPs are identified. Table 9 shows the net farm income and soil loss arising from various situations of yield response accompanying terracing for all farm models.

Table 10 summarizes the production decisions for the large farm models when continuous cropping is not available as a BMP. The rotation with the least amount of fallow was selected as the most economical. This was a winter wheat (25 percent) — fallow (25 percent) and spring barley (50 percent) rotation. While the BMP selection remained the same as predicted earlier, net farm income was lower and soil loss higher when fallow was included in the rotation.

Conclusions

This publication analyzed the effects of implementing measures to control soil erosion on a representative small and large sized dryland farm in the upper precipitation zone of the Upper Snake River Basin. The

Table 8. Impact of the BMPs on net farm income, soil loss and rotation on a representative 2,200-acre farm in the Upper Snake River Basin.

BMP scenarios / Models	Original program: No yield increase for terracing	Terracing programs: 2.5% yield increase for terracing	5% yield increase for terracing	10% yield increase for terracing
I. Unrestricted model				
Net farm income	$157,872	$157,872	$157,872	$160,889
Soil Loss	8,690	8,690	8,690	7,121
(tons/acre)	(3.95)	(3.95)	(3.95)	(3.24)
Rotation[1]	W-B	W-B	W-B	W-B
BMPs[2]	None	None	None	Terraces
II. Level one constraints				
Net farm income	$155,554	$155,554	$155,790	$160,889
Soil loss	7,500	7,500	7,500	7,121
(tons/acre)	(3.41)	(3.41)	(3.41)	(3.24)
Rotation	W-B	W-B	W-B	W-B
BMPs	Strip crop	Strip crop	Terraces	Terraces
III. Level two constraints				
Net farm income	$149,578	$151,187	$152,943	$158,707
Soil loss	6,000	6,000	6,000	6,000
(tons/acre)	(2.73)	(2.73)	(2.73)	(2.73)
Rotation	W-B	W-B	W-B	W-B
BMPs	Min. till Strip crop Terraces	Strip crop Terraces	Terraces Strip crop	Terraces Strip crop
IV. Level three constraints				
Net farm income	$136,224	$139,106	$141,987	$147,751
Soil loss	4,688	4,688	4,688	4,688
(tons/acre)	(2.13)	(2.13)	(2.13)	(2.13)
Rotation	W-B	W-B	W-B	W-B
BMPs	Min. till Terraces Strip crop G. water	Min. till Terraces Strip crop G. water	Min. till Terraces Strip crop G. water	Min. till Terraces Strip crop G. water

[1]Crop rotation: W-B = winter wheat (50 percent) — spring barley (50 percent).

[2]BMPs: Min. till = minimum tillage; strip crop = strip cropping; terraces = terracing, G. water = grass waterways.

practices considered included continuous cropping, crop residue management, terracing, strip cropping and grass waterways.

These BMPs are all effective in reducing soil erosion. Applying the BMPs at their maximum levels caused an average reduction in soil loss of 55 percent for the two farms studied. Soil losses average 4.5 tons per acre when no soil erosion control measures were used on the farms. A soil loss of approximately 2 tons per acre was achieved with institution of the entire package of BMPs.

Implementation of all the BMPs except continuous cropping represents a cost to the farm operator. Elimination of summer fallow from the crop rotation contributed an average of $24 per acre to net farm revenue for the two farms studied. Of the other BMPs, crop residue management had the lowest average cost per acre followed by strip cropping, terracing and grass waterways.

The linear programs present information on which practices reduce income the least for a given amount of soil loss. Continuous cropping actually contributes to net farm income and was adopted for the farms before soil loss was constrained. For the small sized farm, strip cropping was the most economical practice when soil loss was limited, followed by terracing. Strip cropping was also identified as the most economical practice on the large sized farm, followed by crop residue management and terracing. As terracing yields were assumed to increase in the models, terracing was steadily substituted for the other practices as the more economical alternative. At a yield benefit of 7.5 to 8 percent, installation of terracing caused an increase in net income on the farms.

Table 9. Effects of varying yield response associated with terracing on a representative 2,200-acre farm with unconstrained soil loss, model I.

	6% yield increase for terracing	7% yield increase for terracing	7.5% yield increase for terracing	8% yield increase for terracing
Net farm income	$157,872	$157,872	$158,007	$158,584
Soil loss (tons/acre)	3.95	3.95	3.24	3.24
BMPs	None	None	Terrace	Terrace
Rotation[1]	W-B	W-B	W-B	W-B

[1]Rotation: W-B = winter wheat (50 percent) — spring barley (50 percent).

Table 10. Impact of BMPs on net farm income, soil loss and rotation on a representative 2,200-acre farm without continuous cropping.

BMP scenarios Models	Original program: No yield increase for terracing	Terracing program: 10% yield increase for terracing
I. Unrestricted model		
Net farm income	$129,932	$131,632
Soil loss	10,340	8,455
(tons/acre)	(4.7)	(3.84)
Rotation[1]	W-F&B	W-F&B
BMPs[2]	Strip crop	Terraces
II. Level one constraints		
Net farm income	$128,081	$131,362
Soil loss	9,000	8,455
(tons/acre)	(4.09)	(3.84)
Rotation	W-F&B	W-F&B
BMPs	Strip crop	Terraces
III. Level two constraints		
Net farm income	$121,863	$129,623
Soil loss	7,000	7,000
(tons/acre)	(3.18)	(3.18)
Rotation	W-F&B	W-F&B
BMPs	Strip crop Terraces	Terraces Strip crop
IV. Level three constraints		
Net farm income	$112,313	$121,315
Soil loss	5,962	5,962
(tons/acre)	(2.71)	(2.71)
Rotation	W-F&B	W-F&B
BMPs	Min. till Terraces Strip crop G. water	Min. till Terraces Strip crop G. water

[1]Rotation: W-F&B = winter wheat (25 percent) — fallow (25 percent) — spring barley (50 percent).

[2]BMPs: Min. till = minimum tillage; strip crop = strip cropping; terraces = terracing; G. water = grass waterways.

The impact on farm income of adopting the most erosion resistant package of BMPs was a reduction of 15 percent to net farm revenues. This impact would be reduced somewhat if terracing was accompanied by an increased yield on the terraced portion of the field. Alternatively, net returns would be reduced by another 17 percent if continuous cropping was not available to insulate farm income from the costs of the other BMPs. To put it another way: net returns for farms that cannot use continuous cropping as a BMP would by reduced by 17 percent regardless of whether they adopted terracing or any other BMP. This occurs because of the loss of productivity related to reduced cropping acreage.

Literature Cited

McCool, D. K., W. H. Wishmeier and L. C. Johnson 1981. Adapting the Universal Soil Loss Equation to the Pacific Northwest. Transaction ASAE.

McDole, R. E., and V. Shiray. 1980. Restricted summer fallow in soil erosion control under dryland crop production. Univ. of Idaho Current Info. Ser. No. 522.

Michalson, E. L., Marie Powell and R. O. Brooks, 1983. Selected Best Management Practices in Southeastern Idaho. Univ. of Idaho CIS 721.

Miller, C. 1978. An engineering analysis of farming terraced and non-terraced dryland wheat farms in Power and Bannock counties of Idaho. Unpubl. M.S. thesis, Dept. of Ag. Eng., Univ. of Idaho, Moscow.

U.S. Department of Agriculture, Soil Conservation Service, ESCS. 1979. Snake River Basin cooperative study, erosion report, Upper Snake River Basin. Forest Service in cooperation with Idaho and Montana.

Walker, D. J., and D. C. Young. 1982. Technical progress in yields — No substitute for soil conservation. Univ. of Idaho Current Info. Ser. 671.

Appendix A
Input Costs By Farm Size

Appendix A, Table 1. Input costs per crop.

Farm size	Crop[1]	Seed lb/acre @ 11-12¢/lb		Anhy. ammonia lb/acre @ 21¢/lb		2-4-D qt/acre @ $3.25/qt		Total cost
Small	AWW	75	$8.25	60	$12.60	0.5	$1.63	$22.48
(700 acres)	WW-F	65	$7.15	40	$ 8.40	0.5	$1.63	$17.18
	SB	70	$8.40	40	$ 8.40	0.25	$0.81	$17.61
Large	AWW	65	$7.15	60	$12.60	0.25	$0.81	$20.56
(2,200 acres)	WW-F	55	$6.05	40	$ 8.40	0.25	$0.81	$15.26
	SB	70	$8.40	50	$10.50	0.25	$0.81	$19.71

[1]AWW = annual winter wheat; WW-F = winter wheat-fallow; SB = spring barley.

Appendix A, Table 2. Operating costs of terracing per crop.

Farm size	Crop[1]	Added fuel, oil lube and repair costs	Added labor costs	Added herbicides, fertilizer and seed costs	Total added operating costs
Small	AWW	$3.16	$0.92	$2.25	$6.33
(700 acres)	WW-F	$3.39	$1.01	$1.72	$6.12
	SB	$3.49	$1.01	$1.76	$6.26
Large	AWW	$2.93	$0.73	$2.06	$5.72
(2,200 acres)	WW-F	$3.20	$1.35	$1.53	$6.08
	SB	$3.10	$0.76	$1.97	$5.83

[1]AWW = winter wheat; WW-F = winter wheat-fallow; SB = spring barley.

Note: Size of farm affects these costs because of: (1) changes in fixed costs related to changes in the farm machinery complements, and (2) the ability of larger farms to spread their fixed costs over more acres.

Appendix A, Table 3. Operating costs of strip cropping per crop.

Farm size	Crop[1]	Added fuel, oil lube and repair costs	Added labor costs	Added herbicides, fertilizer and seed costs	Total added operating costs
Small	AWW	$2.20	$0.92	$2.25	$5.37
(700 acres)	WW-F	$2.35	$1.01	$1.72	$5.08
	SB	$2.42	$1.01	$1.76	$5.19
Large	AWW	$2.03	$0.73	$2.06	$4.82
(2,200 acres)	WW-F	$2.22	$1.35	$1.53	$5.10
	SB	$2.15	$0.76	$1.97	$4.88

[1]AWW = winter wheat; WW-F = winter wheat-fallow; SB = spring barley.