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Soil Conservation and Farm Management Planning

A Descriptive Economic Model

J. Michael Harker
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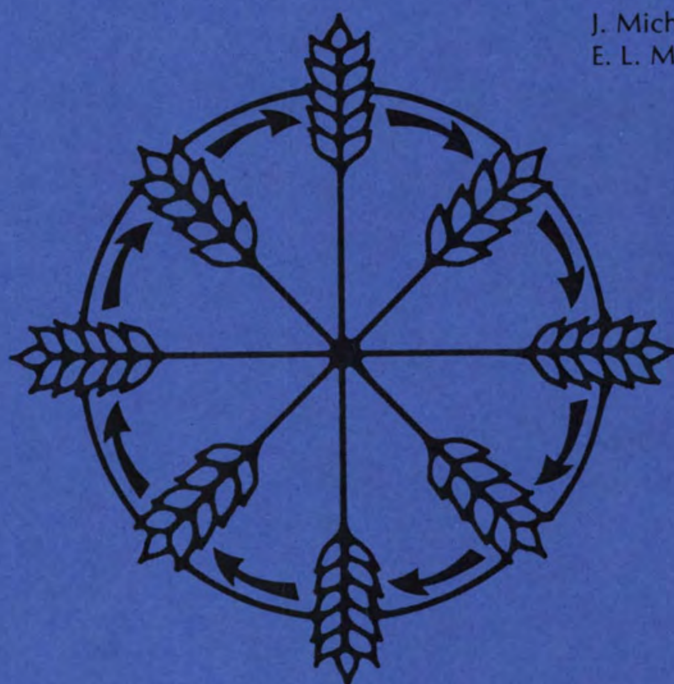

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Soil Conservation and Farm Management Planning

A Descriptive Economic Model

J. Michael Harker E. L. Michalson

Soil erosion is a persistent problem in the Palouse area. Concern over this problem has been greatly amplified in recent years as a result of PL 92-500, the Federal Water Pollution Control Act Amendments of 1972. One goal of that act is to eliminate the discharge of pollutants into the nation's streams by 1985. Regarding agriculture specifically, Section 208 of the act requires establishing a regulatory program to identify agriculturally related nonpoint sources of pollution from land used for livestock and crop production, and to ". . . set forth procedures and methods (including land use requirements) to control to the extent feasible such sources (9)."

For agriculture in general, and particularly for the Palouse, the implications of this legislation focus largely on the problems of soil erosion and concurrent sediment transportation. A report presented to the President by USDA in 1970 points out, "from the standpoint of quantity, sediment resulting from soil erosion of the land is the greatest contributor to pollution of surface waters (2)." Thus, abatement of runoff-caused soil erosion is an essential requirement under the goals of PL 92-500.

Research Objectives

Unfortunately, reducing soil loss is not independent of other changes. Among such related changes are the economic effects associated with soil conservation. Since the burden of reducing soil loss falls on the individual agricultural producer, the principle economic effects also accrue to his enterprise.

The purpose of this bulletin is to discuss the results of research to develop an analytic method for estimating on-farm economic parameter variation associated with increased erosion control effectiveness in the Palouse area. Specifically, a fundamental goal has been to develop an economic model incorporating, as a soil loss estimator, the Universal Soil Loss Equation (USLE) as adapted to Pacific Northwest conditions by Dr. D. K. McCool[1]. The USLE is A = RK<u>LS</u>CP, where A is calculated average tons of soil loss per acre per year, R the rainfall and runoff factor, K the soil erodability factor, LS the slope length and steepness factor, C the cropping management factor and P the erosion control practice factor (10).

The steepness, irregular slope and irregular yet frequent hills in the Palouse area generally preclude such conventional conservation practices as strip cropping and terracing. As a result, the P factor in the original USLE formulation, which relates the influence of these practices to average soil loss, is not directly relevant. Thus, in adapting the USLE for prediction purposes in the Palouse area, the P factor assumes a constant value of 1.

The first three factors in the equation, R — rainfall, K — soils and LS — slopes, relate to naturally occurring environmental conditions which are beyond a farm manager's control. Since the P factor is a constant and the determinants of the R, K and LS values are not alterable, cropping and tillage management, represented by the C factor, is the only practicable soil erosion variable that can be influenced by the farm manager.

The major objective of this research was to compare specific erosion controlling crop management practices and their effectiveness with their direct effects on the incomes of Palouse farmers in the short run.[2] Such comparison identifies the economic trade-off positions, in relation to varied soil loss conditions, of the full range of cropping and tillage systems commonly encountered in the Palouse area.

Study Area

The Palouse area has considerable variation in soil types and climatic conditions. As a result, agricultural practices also vary. For example, the eastern part of the Palouse receives sufficient precipitation for annual cropping while further west lower precipitation precludes annual cropping. With such divergence, farm management analysis must be directed specifically to sub-regions of the Palouse area where the physical environment is relatively homogeneous. The area, approximately homogeneous in soils and rainfall, delineated for this study stretches from Colfax, WA in the northwest to Genesee, ID in the southeast (Fig. 1). It averages approximately 18 miles wide. Average annual rainfall in the area is from 18 to 23 inches and soils are predominantly of the Naff-Thatuma-Palouse-Tilma and Caldwell-Latahco associations.

Analytic System

A linear programming (LP) model was used to estimate economic impacts of soil loss abatement on farm income. Through LP techniques, a comprehensive set of alternative cropping and tillage practices is structured and evaluated in light of erosion abatement effectiveness and economic viability.

Three quantitative components are essential to the use of linear programming — a quantifiable objective, a variety of methods or processes for achieving that objective and resource or other restrictions (5). To comply with these requirements, this analytic system maximizes the total dollar value of crops produced less all production costs except interest on investment in land, improvements and equipment and the costs of depreciation and taxes. More generally the maximized value can be termed net earnings.

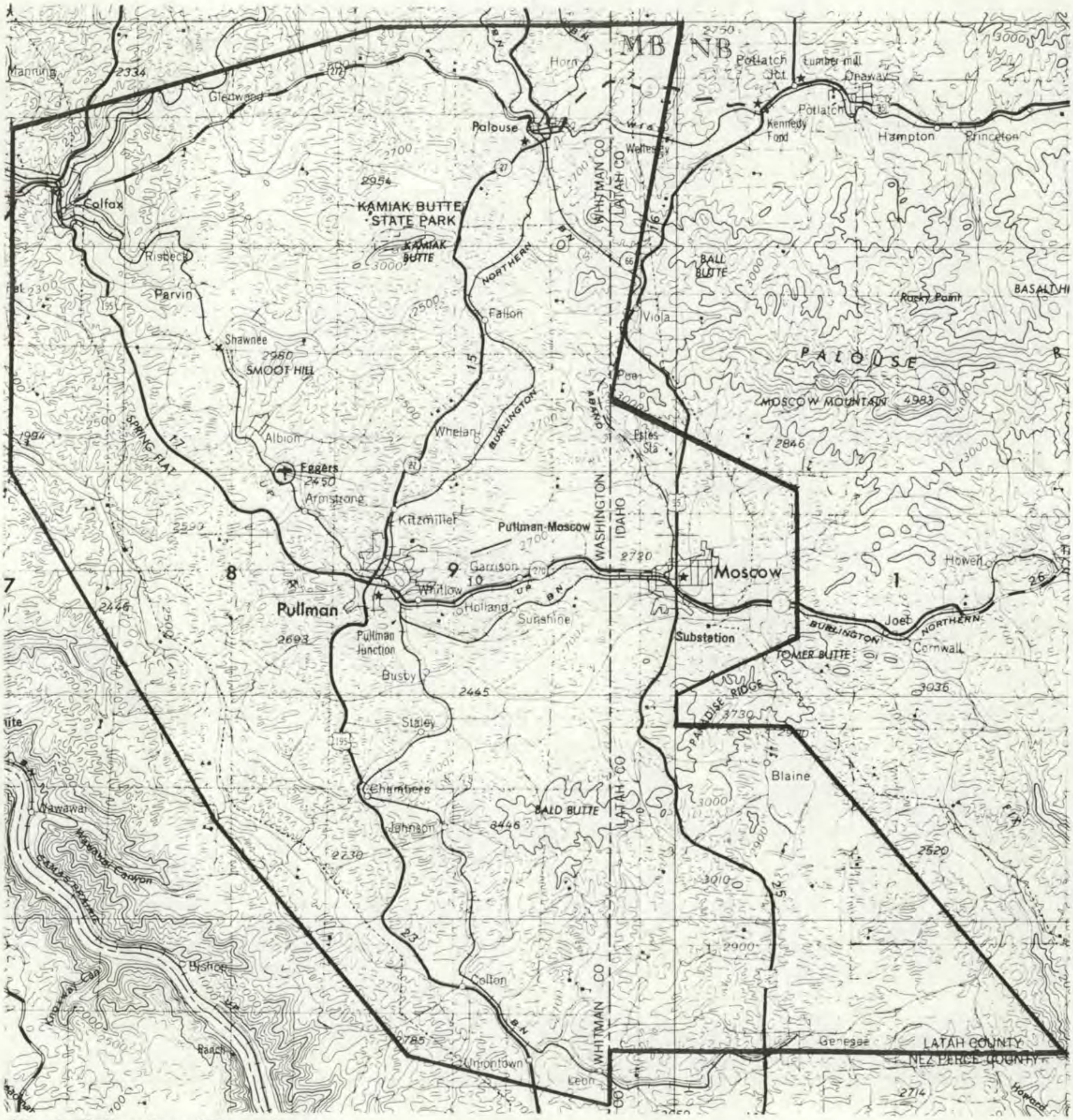

Fig. 1. Delineation of the study area.

Such an objective is assumed consistent with the immediate objectives of the individual farm manager.

The production of specific crops with different tillage and associated herbicide programs and the subsequent sales of product provide alternative activities for achieving the objective. Allowable soil loss due to runoff provides the principal restriction. Further restrictions include available land and crop rotation requirements. The generalized form of the model[3] is:

$$\text{Maximize} \quad Z = -c_1x_1 - c_2x_2 - \dots - c_nx_n + P_1Q_1 + P_2Q_2 + \dots + P_rQ_r$$

$$\text{subject to} \quad a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leqslant b_1$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \leqslant b_m$$

$$x_j \geqslant 0$$

where:

- Z = net return providing payment to management and the expenses of fixed factors of production,
- x_j = the acreage level of the jth production technique applied on high ground or low ground (j = 1,2 ... n),
- Q_k = quantity of the kth commodity produced (k = 1,2 ... r),
- c_j = total per acre production costs of the jth production activity excluding expenses associated with short run fixed investment,
- P_k = market prices of the k producible commodities,
- a_{ij} = the ith production requirement or technical production relation coefficient for the jth activity (i = 1, 2 ... m), and
- b_i = resource limits over i classes of resources including land available and allowable soil loss.

Activities

Activities included in the model can be classed as real, artificial or disposal. The nonreal activities are relevant only to mathematical functioning of the model and are not discussed here.[4] The real activities can be broken into two classes: production and sales. Sales activities simply represent the revenue-generating process of selling commodities produced. Each production activity includes a combination of one crop — winter wheat, spring barley or field dry peas — and a specific tillage and chemical program. Because of differences in erosion potential, yield and input requirements, production activities are also differentiated by crops preceding a given crop. For example, winter wheat following winter wheat and winter wheat following dry peas are each considered unique activities. Table 1 presents a complete listing of all production activities considered.

Assumptions Affecting Activities

Each crop production activity includes an herbicide program that is assumed capable of maintaining effective weed control. Winter wheat is not allowed to follow spring barley because of problems with volunteer barley in the wheat crop.

Three years of continuous wheat is the maximum allowed by the model since preliminary test data indicate that more than three years of uninterrupted wheat results in severe yield reduction.[5] Barley can enter either as an annually seeded crop or as a component part of a rotation. In Table 1, the activities "continuous cropped spring barley" provide for annual seeding of barley. "Spring barley after winter wheat" and "recropped spring barley" allow barley to enter as a rotational component with up to 5 years' successive seedings.

Activities are also differentiated as to production on low ground or on hillsides and hilltops. In the Palouse area, the complexity of topography precludes cropping and tillage planning unique to land capability class.[6] However, the dominance of contour tillage in the area results in hills and low ground farmed as separate fields. This has traditionally provided a basis for applying different management practices to high versus low ground. Based on this, all activities have two replications. All combinations of crop and tillage can be applied to high ground or low ground. Twelve percent slope was used as the point of delineation.

Constraints

Basic land, erosion and rotational constraints are included in the model. The land constraints are farm unique inputs into the model. They restrict the model to be consistent with the land resource available on the farm analyzed. There is one constraint for low and one for high ground acres.

The erosion constraints parallel the form of land constraints. They require that the sum of the soil loss from the total acreage in each of the production activities is not to exceed a specified total soil loss level. The constraints can be set at any specified level or can be allowed to vary to force reanalysis at evenly dispersed points throughout a range.

The rotation constraints are quite different from the erosion and land constraints. They are unique to the model and remain constant for any farm analyzed and for any erosion constraint considered. Their purpose is to insure that model output, which is in the form of a one-year plan, can be transformed into a crop rotation plan. Since we defined crop activities with regard to the previous year's crop, rotation constraints were necessary to insure consistency. For example, the acreage of winter wheat following dry peas could not logically be greater than the acreage of dry peas. The full system of rotation restrictions is:

$$WWAP_i = DP_i$$

$$RW2_i \leqslant RW1_i \leqslant WWAP_i + WWAF_i$$

$$RB4_i \leqslant RB3_i \leqslant RB2_i \leqslant RB1_i \leqslant SBAWW_i \leqslant WWAP_i + WWAF_i$$

where i = high ground or low ground.[7] Other symbols are identified in Table 1.

Data Development

Possibly the most basic problem in this study was determining the range of agronomic practices employed within the study area. Identifying farm structure,

Table 1. Crop-tillage combinations considered. (Crop, tillage and low vs. high ground fields results in a combinational total of 162 linear programming activites.)

Crops to which Tillage Is Applicable	ID Code for Tillage Plan	Number of Times Field Is Covered with Each Tillage Implement: Chisel Plow	Moldboard Plow	Field Cultivate	Rodweed	Disc	Spike Tooth Harrow
Winter Wheat after Fallow	A1	1		1	3		
(WWAF)	A2		1	1	3		
	B		1	2	8		
	C		1	2	8		2
Winter Wheat after Dry Peas	A1			1			
(WWAP)	A2					1	
	B1	1			1		
	B2				1	1	
	C1				1	1	1
	C2	1		1		1	
	C3				1	2	
First Year Recropped Winter	A					1	
Wheat	B1	1				1	
(RW1)	B2		1			1	
Second Year Recropped Winter	B3	1				1	1
Wheat	B4	1				1	1
(RW2)	C1		1		1	1	1
	C2			2		2	
Spring Barley after Winter	A1	1		1			1
Wheat	A2		1	1			1
(SBAWW)	B1a	1		2			1
First, Second, Third, or Fourth	B1b	1		1	1		1
Year Recropped Spring Barley	B2a		1	2			1
(RB1), (RB2), (RB3), (RB4)	B2b		1	1	1		1
Continuous Cropped Spring Barley	C1	1		2	1		2
(CB)	C2		1	2	1		2
Dry Peas	A1	1		2			1
(DP)	A2		1	2			1
	B1a	1		2	1		1
	B1b	1		2	1		2
	B2		1	2	1		1
	C1a	1		3	1		1
	C1b	1		3	1		2
	C2		1	3	1		2

particularly equipment and machinery, associated with particular agronomic programs was also essential. These data were obtained in personal interview with 73 area farmers randomly chosen from the population of 366. This data set included complete physical and economic specification of farm implements, tillage, cropping, chemical programs, seeding rates and dates, manager experience and general farm descriptions.

Average farm size for the area was approximately 1,100 acres. An equipment set capable of handling standard cropping practices for the average size farm was determined from survey data. Specific machinery and implements selected were those most commonly found on farms of near average size. Two physical areas of approximately 1,100 acres were then delineated from the overall study area, one to represent the steeper portions of the Palouse and the second to represent only moderately steep topography. The steeper farm is identified as the Colfax farm, the other as the Genesee farm. The two areas are presented in Figs. 2 and 3. These physical areas and the selected equipment component served as "typical farms" for the analysis.

Average LS values were calculated for each area based on 7.5 minute USGS topographic maps. Those values were 2.02 for low ground fields and 3.12 for high ground fields on the Genesee farm. On the Colfax farm, all ground was greater than 12 percent slope which makes it high ground by definition. Average LS value was 4.90 for all land on the farm. The K factor for both farms was .32; R factors were 35 for the Genesee farm and 32 for the Colfax farm (3).

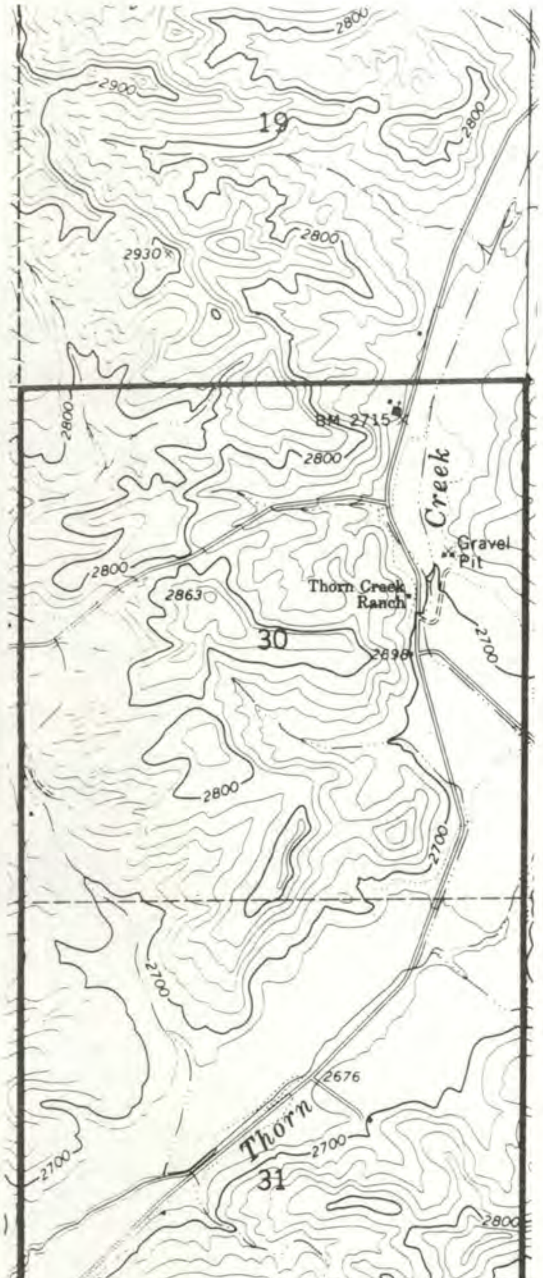

Fig. 2. Genesee farm delineated on 7.5 minute topographic map.

Fig. 3. Colfax farm delineated on 7.5 minute topographic map.

Appendix A shows the calculated C factors for each crop-tillage combination and the multiplicative products of R, K, LS and C, which are the estimates of average annual soil loss per acre for each cropping activity.

Data describing production parameters were provided by farm survey information. A partial budget routine developed by G. E. Rodewald[8] provided cost information on equipment operation while survey data was used to estimate input levels, input costs, output levels and output response to various inputs. Complete cost information and yield estimation for each production activity is shown in Appendix B.

Standard Output

The output provided by the basic model is an optimum production plan, although not necessarily a unique optimization. It is optimal in the economic sense that the net return providing payment to management and to expenses of fixed factors of production has been maximized subject to specified constraints including available land and allowable soil loss. Such optimization results from appropriate specification of crop rotation and choice of tillage methods specific to each crop within the rotation. Thus, analytic output includes identification of the rotation created within the system and the tillage program for each crop. Implicit in the selection of rotation and tillage is accompanying pesticide, fertilizer and seeding rates as internally specified.

In addition to suggesting an optimum plan, the system also offers a detailed economic description of that plan. Principally provided is the net earnings value which is maximized within the analytic system. Based on this net earnings value, the marginal value product (MVP), or dollar value increase of output per unit increase of resource used, is specified for each constraining factor including soil loss. In the case of soil loss, MVP is a valuation not of the resource soil itself but rather an estimate of the *value of the right* to allow soil to be lost from the farm through erosion. This value in no way accounts for any potential costs, via production declines, associated with erosion-caused soil degradation.

Tentative Analyses

The net earnings value maximized within the system must pay the farm expenses of depreciation in equipment and land improvements, pay property taxes and provide a return on the investments in land, land improvements and equipment. After paying these expenses, the remainder is return to management.

When only depreciation and property taxes are deducted from the value maximized within the system, the balance is net return to management and fixed investment. This net return is the taxable income for the unincorporated farm enterprise with free and clear ownership of all fixed factors of production.

The Mathematical Programming Systems/360 used for analyzing the model also allows analysis when constraints are specified over a range rather than at a fixed value (6). Through this option, a production function can be defined where net return to management and fixed investment is functionally related to the level of soil loss allowed. The causative variables, tillage and cropping, can then be analyzed in relation to the various segments of this production function. To facilitate this option, the soil constraint was increased from zero to a maximum feasible average tons per acre soil loss at increments of 0.25 tons per acre.

Genesee Farm

Total value of equipment for the synthesized farms used in analysis was $157,700.[9] The combined value of a shop and an equipment storage shed was estimated to be $31,400. The depreciation expense of this combined investment is estimated at $15,765 per year. This expense and an assumed property tax of $4.50 per acre are deducted from the value maximized within the system to arrive at estimated net return to management and fixed investment.

Net return to management and fixed investment and the rotational scheme to realize that return are related concurrently to the level of soil loss in Fig. 4. The maximum level of economically feasible soil loss is approximately 9 tons per acre. This implies that for a farm comparable to the synthesized Genesee farm, average soil loss in excess of 9 tons per acre can be attributed only to poor management. Although cropping and tillage plans resulting in higher erosion levels are possible within the model and are being used within the Palouse area, this analysis indicates that the marginal economic return associated with erosion in excess of 9 tons per acre is zero or negative. Thus, the plans developed for 9 tons per acre soil loss maximize net return regardless of soil loss consideration.

At this level, net returns to management and fixed investment are $110,555. On fields composed of hillsides and hilltops, a wheat-pea rotation is suggested where C-2 tillage and the associated chemical program are applied to wheat ground. Similarly, C-la is suggested for pea ground. For the low ground fields, a wheat-wheat-wheat-pea rotation is suggested. The accompanying tillage program is C-1 for the winter wheat crop following peas, B-3 tillage for first and second year recropped wheat and C-la tillage for the pea crop.

Results indicate that the Genesee farm can reduce soil loss from 9 to 6 tons per acre with the least reduction in net returns by maintaining the same rotations but changing to B-1 tillage on both the high ground wheat crop and the low ground winter wheat crop after peas. Tillage for all other crops would remain unchanged. Such a change would reduce net returns to management and fixed investment by $2,872. The average cost of this 3 tons-per-acre reduction in soil loss would be $2.61 per acre, or $ .87 per ton.

Analysis indicates a shift in rotation is necessary to reduce soil loss below the 6-ton level. To maximize net returns while limiting average soil loss to 5 tons per acre, a wheat-barley-pea rotation is required for high ground.

Low ground rotation and tillage would remain essentially unchanged as would high ground tillage for wheat and pea crops. The barley crop receives B-lb tillage. Net returns to management and fixed investment would be $104,487, an

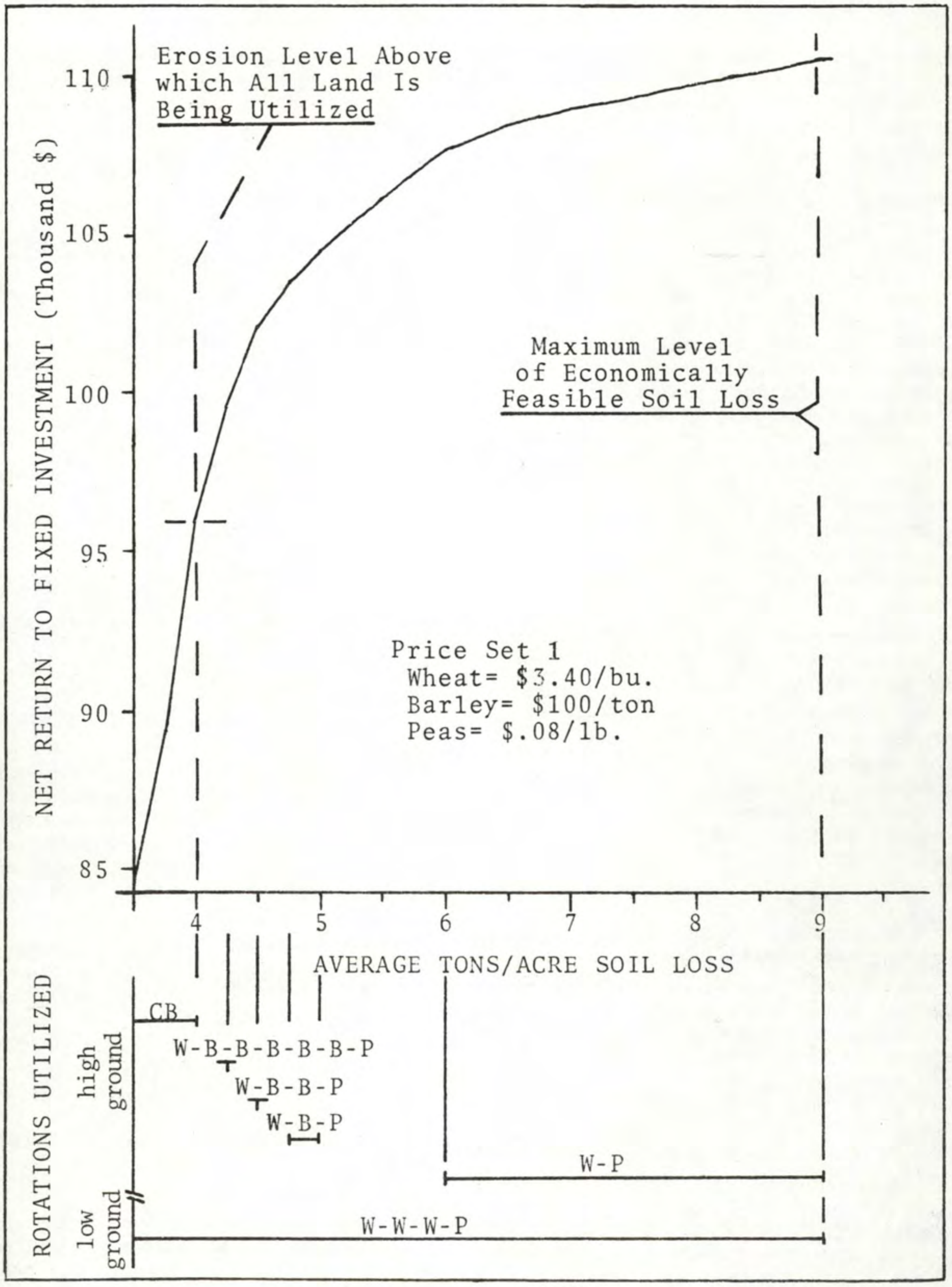

Fig. 4. Net income, based on price set one, and crop rotations as both relate to soil loss on the Genesee farm. (Discontinuity of rotation specification signifies a combination of the rotations preceding and following.)

additional $3,195 reduction. Marginal valuation of this average 1-ton reduction is $2.91 per ton. A complete description of the farm plan associated with a 5-ton per acre average annual soil loss rate is presented in Table 2.

Reducing soil loss below the 5-ton level requires the same low ground rotation, but with reduced tillage. For high ground, tillage must be reduced to B-la for the pea crop and rotation must be expanded by including more barley. A wheat-barley-barley-pea rotation is required at 4.5 tons per acre and a wheat-barley-barley-barley-barley-barley-pea rotation is needed at approximately 4.2 tons per acre. At 4 tons soil loss per acre, continuous barley with tillage B-lb is required on high ground. The low ground management required at this point is a tillage program of B-1 tillage on winter wheat after peas, tillage A on first year recropped wheat, B-1 on second year recropped wheat and B-1 on peas. Reducing from 5 to 4 tons the average soil loss per acre results in a total reduction of 1,100 tons and a marginal value of $7.68 per ton. Below 4 tons per acre, reductions in the average soil loss from the entire farm are accomplished by retiring land from production. (The model assumes that land retired from production yields zero erosion.)

Colfax Farm

The heterogeneity of topography within the Palouse area is an important variable in this study. Analysis of the Colfax farm, with its topography, emphasizes the differences in profitability and farm management requirements within the Palouse area.

Since the equipment package is the same on both synthesized farms, depreciation expense is the same. Taxes are also assumed equal on both farms.

As with the Genesee farm, the maximum level of economically feasible soil loss for the Colfax farm is not changed over the range of commodity prices considered. This maximum economically feasible level is approximately 15.6 tons per acre. The management plan at this erosion level is a wheat-pea rotation with C-2 tillage for winter wheat and C-la tillage for peas. With this plan, net returns to management and fixed investment are $94,529. Since the Colfax farm has no land less than 12 percent slope, one management scheme applies to the entire farm. Analysis at various soil loss levels is presented in Fig. 5.

Analysis indicates average soil loss can be reduced from 15.6 tons to 10 tons per acre by tillage reductions alone. This requires changing only to B-1 tillage for the winter wheat crop. Maximum net returns to management and fixed investment at this 10-ton erosion level are $91,356. Thus, reducing soil loss by 6,177 tons reduces net returns by $3,173. This is an average opportunity cost of $2.88 per acre for the 1,100-acre farm, or $.51 per ton of soil conserved.

Soil loss is reduced to approximately 7.75 tons per acre by expanding the rotation to three years, including spring barley with tillage B-la between the wheat and pea crops. The average opportunity cost to reduce soil loss this additional 2.25 tons per acre is $1.95 per ton, or $4,833 for the entire farm. Net returns to management and fixed investment are $86,522 at this soil loss level.

Further reduction to approximately 7.3 tons soil loss per acre can be attained by reducing pea tillage to the B-la level within this same rotation. Beyond this point, the most economical way to reduce erosion is to include more barley within the rotation. At the 7-ton level, a wheat-barley-barley-pea rotation is required. Tillage is unchanged. To control soil loss between 6.5 and 6.75 tons per acre requires a rotation of wheat-barley (5-years)-peas.

A constraint of 6.25 tons per acre average soil loss appears to be the minimum achievable without retiring land. At this level, the suggested management plan is continuous spring barley with B-lb tillage. Opportunity costs for reducing soil losses from 7 to 6.25 tons per acre are $6,334, or $5.76 per acre. Net returns to management and fixed investment for such a plan are $77,262.

Conservation Costs and Farm Debt

The economic effect of soil conservation must be assessed in terms of each individual farm situation. Since few farms are totally owner-financed, the debt situation of the farm becomes particularly important. As an example, consider the following:

Assume that the Genesee farm had been purchased at a price of $1,000 per acre at the beginning of the 1972-73 crop year. Purchase required a 30 percent down payment, with the balance financed through a 30-year Federal Land Bank mortgage at 8.5 percent interest. Assume also that the entire equipment package was purchased new and that the shop and equipment storage shed were built at the same time. Purchase price of the equipment was $157,700 and cost of the two buildings was $31,400. Again, the purchaser paid 30 percent down and financed the balance on a 10-year Production Credit Association contract at 10 percent interest. Annual payment requirements would be $71,650 on land, $21,545 on equipment and improvements, for a total payment burden of $93,195.

When the total payment is deducted from estimated 1975 net return to management and fixed investment for the Genesee farm ($110,955 at 9-ton soil loss level), the owner has $17,360 remaining to pay income tax and as disposable income. At soil loss constraints of 6, 5 and 4 tons per acre, the owner's balance is $14,488, $11,292 and $2,844, respectively.

Realize, however, that the portion of land, improvements and equipment payments applied to the loan principal is taxable income. Since payments due in 1975 are the third annual payments on loans initiated at the beginning of the 1972-73 crop year, $3,090 of the equipment and improvements payment and $7,300 of the land payment would be payment to principal. Therefore taxable income would be $27,750 for the Genesee farm under a 9-ton per acre soil loss management program, $24,878 at 6 tons per acre, $21,682 at 5 tons per acre and $13,234 at 4 tons per acre.

Assuming a family of four, filing jointly and taking a standard deduction, federal income tax for these incomes would be $4,948, $4,057, $3,163 and $1,286. Therefore, after payment of interest and principal on all loans, payment of income taxes and payment of all other expenses, disposable income for the farm family would be $12,412 if no effort was made to control erosion. If erosion were constrained at 6 tons per acre, disposable income would be $10,431; at 5 tons

Table 2. A profit-maximizing farm plan allowing 5 tons per acre average soil loss for the synthesized Genesee farm.

ROTATIONS →		LOW GROUND: Wheat —	Wheat —	Wheat —	Peas	HIGH GROUND: Wheat —	Barley —	Peas
TILLAGE PROGRAM		B-1 chisel rod weed	B-3 chisel disc harrow	B-3 chisel disc harrow	C-1a chisel fld cult(3X) rod weed harrow	B-1 chisel rod weed	B-1b chisel fld cult rod weed harrow	B-1a C-1a chisel fld cult(2.5X) rod weed harrow
PESTICIDE PROGRAM Type Application Rate % Field Covered		Chiptox * 3 qt./ac 100% Banvel-D * 2 oz./ac. 75% Carbyne 1 qt./ac. 50%	Chiptox * 3 qt./ac 100% Banvel-D * 2 oz./ac. 75% Carbyne 1 qt./ac. 50%	Chiptox * 3 qt./ac 100% Banvel-D * 2 oz./ac. 75% Carbyne 1 qt./ac. 100%	Synox 2.5qt./ac. 100% Avadex 1.25qt./ac. 100% Imadan 2 lb./ac. 50%	Chiptox * 3 qt./ac 100% Banvel-D * 2 oz./ac. 50% Carbyne 1 qt./ac. 25%	Chiptox 3 qt./ac. 100% Avadex 1.25qt./ac. 50%	Avadex 1.25 qt./ac. 100% Synox 2 qt./ac. 75% Imadan 2 lb./ac. 50%
FERTILIZER actual lb/acre	N	105 *	124 *	124 *	0	105 *	62 *	0
	S	16 *	16 *	16 *	0	16 *	14 *	0
	P	34	34	34	0	34	0	0
SEEDING RATE lb/acre		77	77	77	175	77	74	175
TOTAL VARIABLE COSTS		$69.44	$76.96	$78.16	$46.14	$68.08	$45.92	$46.63
ESTIMATED YIELD/ACRE		72 bu.	67 bu.	67 bu.	1517 lb.	58 bu.	1.35 tons	1440 lb.

*Both chemicals applied jointly with one application.

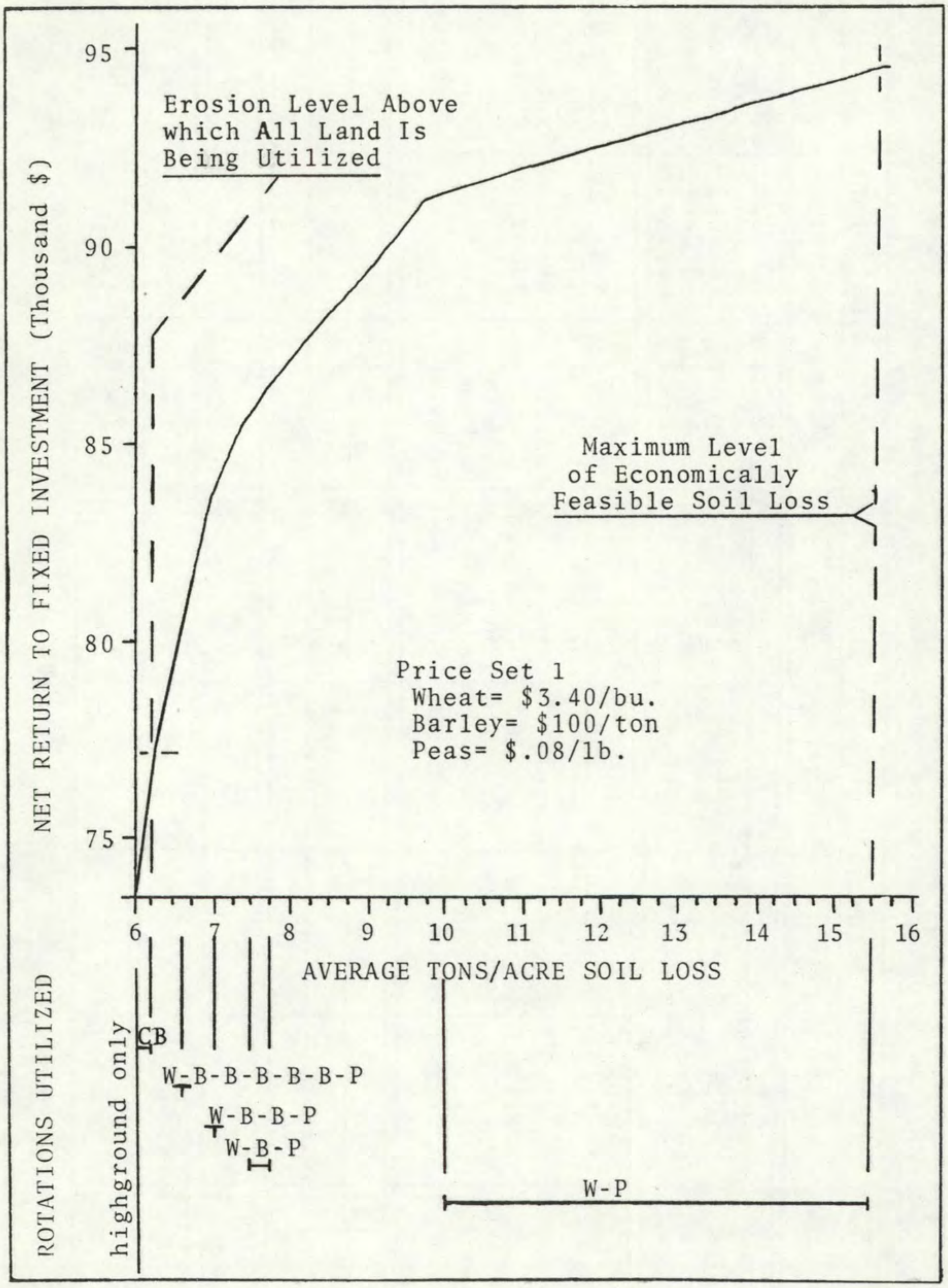

Fig. 5. Net income, based on price set one, and crop rotations as both relate to soil loss on the Colfax farm. (Discontinuity of rotation specification signifies a combination of the rotations preceding and following.)

per acre, $8,129. The effects of 4-ton per acre constraint would be severe on the farm family with as little owner equity as in this example. Disposable income would be reduced to $1,558.

Comparative Summary

Certain trends are apparent from the production functions developed over the ranges of topographic and economic variables considered. The analyses consistently demonstrated that barley must be included in the rotation to achieve minimal soil loss. In all analyses conducted, barley eventually enters the high ground rotation as soil loss becomes more restrictive.

In low ground rotations, wheat was dominant. In all analyses with low ground, a wheat-wheat-wheat-pea rotation was suggested.

Although analyses based on average 1975 prices indicates reduced tillage is the least-cost way to reduce erosion, the inconsistency of this finding over varied prices limits the confidence of such a conclusion. In all cases tillage reduction is necessary for any appreciable reduction in soil loss. However, analysis under varied commodity prices suggests that the frequency of peas in the rotation must also be reduced, primarily because of the highly erodable nature of soil following a pea crop. Lack of residue from peas leaves the soil almost totally exposed as it enters critical winter and early spring periods.

Analysis of farms representing two different topographic conditions demonstrated the importance of this variable. Although management plans are nearly identical for high ground on both, the soil loss associated with any particular plan is very different. Marginal reductions in soil loss can be achieved on either farm by making similar changes in management practices. However, attainment of a set standard on soil loss requires totally different management practices on the two farms.

Conclusions and Recommendations

This analytic system approximates the short run economic situation within which Palouse area farmers can regard their soil conservation efforts. This assessment method will give state and federal agencies a more objective basis on which to offer individual soil conservation and farm planning assistance to farm managers. A comprehensive farm plan can be developed that gives consideration to specific topography, innate fertility and existing equipment of the individual farm. Such a plan, simultaneously considering both erosion and economics, provides a concise description of the projected erosion levels and the economic structure associated with crop production. This approach is consistent with guidelines in Section 208 of PL 92-500, which state that runoff from agricultural land in crop production is to be controlled "to the extent feasible" where economic factors are included in defining feasibility (9).

To assess the "economic feasibility" of an erosion control program, the economics of the individual producer must be considered first. Although long-run economics are the ultimate criteria for ascertaining the feasibility of established standards, the short-run economics define the economic feasibility of making initial compliance with such standards. This analytic system allows estimation of short-run economic effects on the individual farm enterprise as they relate to initial compliance with any set standard on the continuum of soil loss levels. This establishes a basis for evaluating, in marginal terms, the economic feasibility of any proposed standard.

Although it is beyond the scope of this research to propose a standard for mandatory erosion abatement, the study has implications for such standards. The effects of standards differ from one farm to the next. In terms of interfarm equity, standards must be made specific to each farm or some form of compensation must be given to farmers more severely affected. To the extent that all farmers are affected by such standards, some degree of compensation seems warranted for all farmers. Secondly, standards set too strictly will force land retirement. The desirability of this must also be considered. Finally, different soil loss constraint levels result in different output mixes. As such differences affect the total supply of various commodities, market prices will also be affected. Although this effect will theoretically stabilize, short run fluctuations must be considered when establishing standards.

Effectiveness of the analytic system is presently limited by three factors: (1) dependence on the accuracy of the USLE soil loss estimates, (2) lack of data defining yield response to seedbed preparation and (3) lack of information defining the negative correlation between herbicide requirements and tillage levels.

The work of Dr. McCool and others in refining the USLE equation for Pacific Northwest conditions has greatly reduced the first problem. As estimates become more precise through empirical testing, this erosion economics model will be more effective. Further research on the LS and C factors is also desirable for efficient use of the model. Since calculating an average high ground and low ground LS factor for each individual farm is laborious, a better method of estimating these average LS factors would improve the cost effectiveness of using this system as an individual farm management planning tool. A standardized system allowing more precise association of specific tillage operations with the C factor would also improve efficiency.

Costs of the herbicide programs included in the LP model are critical to the analysis. The herbicide programs and the effects of yield response to tillage have been "best-guess" approximations in this analysis. Since the sale of crops generates the gross returns to farm production, these yield parameters also require more precise estimation. Concentrated research directed at answering the questions of yield and herbicide association with tillage is now in progress.[10]

The economic sensitivity of farm management planning to yield response and herbicide needs associated with tillage level has been demonstrated in this economic study. This offers a basis for establishing the precision level required of research results on tillage, herbicides and yields.

Similarly, economic research must continually progress with results of physical and biological research. The basic model presented in this bulletin can be adapted to assess economic aspects of newly developed cropping and tillage schemes suggested by agronomic research. Although physical and biological research needs to better identify the parameters specified in this analytic system, economic research also has an obligation to clarify monetary parameters which ultimately guide farm producers in their management planning process.

Through well coordinated research among the involved disciplines, this model can also be adapted for application in other geographic areas. A total respecification of parameters and relevant cropping and tillage plans would be needed, but the basic concept and structure of this model could be retained. Rotations would be a product of, rather than an input to, the system. Also the farm-specific nature of this system would be retained, and the ability to differentiate management practice by topographic differences within the farm could be adapted to the specific conditions of other areas.

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[1]The Pacific Northwest adaptation of the USLE provides a "first generation" method of soil loss estimation. Current status of development of that adaptation is discussed in *Sheet and Rill Erosion Control Guide — State of Washington* (8).

[2]Short run here is defined as a time sufficiently short that equipment investment costs may be viewed as fixed. It was beyond the scope of objectives to consider the planning range that would be sufficiently long to allow investment in equipment and the equipment investment crop-input costs of interest change and depreciation to be viewed as unrestricted planning variables rather than fixed factors.

[3]For presentation of the model in complete form see Harker (4).

[4]Heady and Candler (5) offer a complete discussion of the mathematics of linear programming modeling.

[5]Unpublished research by R. W. Harder. Agricultural Experiment Station, University of Idaho, Moscow.

[6]Noteworthy LP-USLE soil conservation economics models have been developed by J. C. Anderson, E. O. Heady and W. D. Shrader (1) and by J. J. Jacobs and J. F. Timmons (7). Both, however, are based on planning unique to land capability class and rely on prespecified rotations.

[7]See Harker (4) for complete explanation of the purpose of rotation restrictions.

[8]Unpublished computer system and user's manual, *A Partial Routine for Calculating Tillage Costs for Dryland Grain Farms*, by G. E. Rodewald, Department of Agricultural Economics, Washington State University, Pullman, WA.

[9]For consistency, 1975 production costs and market prices were used in this analysis. Other prices were also used to test price sensitivity and are reported in Harker (4).

[10]Research directly applicable to these questions is underway in the Pacific Northwest States through the STEEP and ERNI projects. STEEP or "Solution to Environmental and Economic Problems" relating to erosion, is a project supported by the Pacific Northwest Wheat Growers, by ARS-USDA and by Agricultural Experiment Stations in ERNI (Erosion Research in Northern Idaho), a study involving yield, herbicide and tillage interrelationships, is a University of Idaho Agricultural Experiment Station project headed by Roger W. Harder, professor, Department of Plant and Soil Sciences.

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Appendix A, Table 1. Calculated "C" factors and predicted values of average soil loss per acre per year.

			Genesee Farm		Colfax Farm
Crop	Tillage	"C" Factor	high ground	low ground	all ground*
Winter Wheat After Fallow (WWAF)	A-1	.40000	13.98	9.05	20.07
	A-2	.79575	27.81	18.00	39.93
	B	.81000	29.36	19.00	42.16
	C	.82050	30.05	19.46	43.15
Winter Wheat After Peas (WWAP)	A-1	.22691	7.93	5.13	11.39
	A-2	.27377	9.57	6.19	13.74
	B-1	.23317	8.15	5.28	11.70
	B-2	.30705	10.73	6.95	15.41
	C-1	.52712	18.42	11.93	26.45
	C-2	.46467	16.24	10.51	23.32
	C-3	.47971	16.76	10.85	24.07
First Year Recrop Wheat (RW1)	A	.11228	3.92	2.54	5.63
	B-1	.14839	5,19	3.36	7.45
	B-2	.39979	13.97	9.04	20.06
	B-3	.22389	7.82	5.07	11.23
	B-4	.71844	25.11	16.25	36.06
	C-1	.78523	27.44	17.56	39.40
	C-2	.30846	10.78	6.97	15.48
Second Year Recrop Wheat (RW2)	A	.09807	3.43	2.22	4.93
	B-1	.12961	4.53	2.93	6.50
	B-2	.37623	13.15	8.51	18.88
	B-3	.19556	6.83	4.42	9.81
	B-4	.67610	23.63	15.29	33.93
	C-1	.73896	25.82	16.72	37.07
	C-2	.26943	9.41	6.10	13.51

Appendix A, Table 1. (continued)

Crop	Tillage	"C" Factor	Genesee Farm high ground	Genesee Farm low ground	Colfax Farm all ground
Spring Barley After Winter Wheat (SBAWW)	A-1	.07116	2.49	1.61	3.58
	A-2	.24711	8.64	5.60	12.41
	B-1a	.07598	2.66	1.72	3.82
	B-2a	.26383	9.22	5.97	13.24
	B-1b	.07398	2.59	1.67	3.72
	B-2b	.25690	8.98	5.81	12.89
	C-1	.10092	3.53	2.28	5.07
	C-2	.35989	12.58	8.14	18.06
First Year Recrop Barley (RB1)	A-1	.11370	3.97	2.57	5.70
	A-2	.31181	10.90	7.05	15.65
	B-1a	.12139	4.24	2.75	6.09
	B-2a	.33291	11.63	7.53	16.70
	B-1b	.11820	4.13	2.67	5.93
	B-2b	.32416	11.33	7.33	16.27
	C-1	.16123	5.63	3.65	8.08
	C-2	.45412	15.77	10.21	22.64
Other Barley Crops (RB2) (RB3) (RB4) (CB)	A-1	.11968	4.18	2.71	6.00
	A-2.	.32822	11.47	7.43	16.47
	B-1a	.12774	4.47	2.89	6.42
	B-2a	.35043	12.25	7.93	17.59
	B-1b	.12442	4.35	2.81	6.25
	B-2b	.34122	11.92	7.72	17.12
	C-1	.16972	5.93	3.84	8.51
	C-2	.47802	16.70	10.81	23.98

Appendix A, Table 1. (continued)

Crop	Tillage	"C" Factor	Genesee Farm high ground	Genesee Farm low ground	Colfax Farm all ground
Dry Peas (DP)	A-1	.12334	4.31	2.79	6.19
	A-2	.31851	11.13	7.21	15.98
	B-1a	.13002	4.54	2.94	6.52
	B-1b	.16000	5.59	3.62	8.03
	B-2	.33568	11.73	7.59	16.84
	C-1a	.15760	5.51	3.57	7.91
	C-1b	.17500	6.12	3.96	8.79
	C-2	.40689	14.22	9.21	20.42

*The Colfax farm is comprised strictly of hillsides and hilltops, no low ground is present.

Appendix B, Table 1. Summary of costs for all crop-tillage processes.

ITEM # a/	CROP	Winter Wheat After Fallow (WWAF)							
	TILLAGE	A-1		A-2		B		C	
	FIELD CLASS	H	L	H	L	H	L	H	L
(1)	SEED b/	6.58							
(2)	FERTILIZER c/	33.34							
(6)	PESTICIDES d/	12.00				6.82			
(9)	CROP INSURANCE	2.70							
(10)	EQUIPMENT EXPENSE e/	4.49		5.93		8.18		8.35	
(14)	LABOR e/	1.96		2.26		3.15		3.37	
(15)	OPERATING CAPITAL EXPENSE	6.11		6.28		6.08		6.12	
(16)	HARVEST	4.21							
(17)	TOTAL VARIABLE COST	71.39	71.39	73.30	73.30	71.06	71.06	71.49	71.49
Y	YIELD/ACRE	73 bu.	83 bu.	73 bu.	83 bu.	73 bu.	83 bu.	73 bu.	83 bu.

Appendix B, Table 1. (continued)

ITEM #	Winter Wheat After Peas (WWAP)									
	A-1		A-2		B-1		B-2		C-1	
	H	L	H	L	H	L	H	L	H	L
(1)	7.91				7.34				6.96	
(2)	36.19									
(6)	9.34	10.32	9.34	10.32	8.08	9.20	8.08	9.20	6.82	
(9)	2.70									
(10)	1.52	1.58	2.68	2.74	2.63	2.70	3.04	3.11	3.10	
(14)	.68	.71	1.21	1.24	1.20	1.24	1.34	1.38	1.47	
(15)	5.83	5.94	6.00	6.11	5.81	5.94	5.87	5.99	5.72	
(16)	4.13									
(17)	68.30	69.48	70.16	71.34	68.08	69.44	68.69	70.04	67.09	67.09
Y	56 bu.	70 bu.	56 bu.	70 bu.	58 bu.	72 bu.	58 bu.	72 bu.	58 bu.	74 bu.

Appendix B, Table 1. (continued)

ITEM #	(WWAP)				First Year Recropped Wheat (RW1)					
	C-2		C-3		A		B-1		B-2	
	H	L	H	L	H	L	H	L	H	L
(1)	6.96				7.91		7.34			
(2)	36.19				39.80					
(6)	6.82				9.34	10.32	9.07	10.18	9.07	10.18
(9)	2.70				2.70					
(10)	4.34		4.71		2.73	2.79	4.00	4.06	5.46	5.52
(14)	1.88			2.06	1.21	1.24	1.81	1.84	2.11	2.14
(15)	5.89		5.93	5.94	6.37	6.48	6.47	6.59	6.65	6.77
(16)	4.13				4.13					
(17)	68.91	68.91	69.32	69.51	74.19	75.37	75.32	76.64	77.26	78.58
	60 bu.	74 bu.	60 bu.	74 bu.	45 bu.	60 bu.	50 bu.	65 bu.	50 bu.	64 bu.

Appendix B, Table 1. (continued)

ITEM #	(RW1)							
	B-3		B-4		C-1		C-2	
	H	L	H	L	H	L	H	L
(1)	7.34				6.96			
(2)	39.80							
(6)	9.07	10.18	9.07	10.18	8.97	9.77	8.97	9.77
(9)	2.70							
(10)	4.13	4.19	5.59	5.65	6.02	6.08	5.57	5.63
(14)	1.97	2.00	2.27	2.30	2.45	2.48	2.40	2.43
(15)	6.50	6.62	6.67	6.80	6.67	6.78	6.62	6.73
(16)	4.13							
(17)	75.64	76.96	77.57	78.90	77.52	78.70	76.96	78.15
	52 bu.	67 bu.	52 bu.	67 bu.	52 bu.	67 bu.	52 bu.	67 bu.

Appendix B, Table 1. (continued)

ITEM #	Second Year Recropped Wheat (RW2)									
	A		B-1		B-2		B-3		B-4	
	H	L	H	L	H	L	H	L	H	L
(1)	7.91		7.34							
(2)	39.80									
(6)	10.32	11.31	10.05	11.17	10.05	11.17	10.05	11.17	10.05	11.17
(9)	2.70									
(10)	2.79	2.86	4.06	4.13	5.52	5.59	4.19	4.26	5.65	5.72
(14)	1.24	1.27	1.84	1.87	2.14	2.17	2.00	2.03	2.30	2.33
(15)	6.48	6.59	6.58	6.70	6.76	6.88	6.61	6.73	6.78	6.91
(16)	4.13									
(17)	75.37	76.57	76.50	77.84	78.44	79.78	76.82	78.16	76.75	80.10
	45 bu.	60 bu.	50 bu.	65 bu.	50 bu.	65 bu.	52 bu.	67 bu.	52 bu.	67 bu.

Appendix B, Table 1. (continued)

ITEM #	(RW2)				Barley Crops (SBAWW),(RB1,2,3,4),(CB)					
	C-1		C-2		A-1		A-2		B-1a	
	H	L	H	L	H	L	H	L	H	L
(1)	6.96				6.66					
(2)	39.80				15.28					
(6)	9.77	10.76	9.77	10.76	13.48				10.15	
(9)	2.70				2.43					
(10)	6.08	6.15	5.63	5.70	2.84		4.29		3.29	
(14)	2.48	2.51	2.43	2.46	1.37		1.67		1.54	
(15)	6.78	6.89	6.73	6.84	3.15		3.29		2.95	
(16)	4.13				3.83					
(17)	78.70	79.90	78.15	79.35	49.04	49.04	50.93	50.93	46.13	46.13
	52 bu.	67 bu.	52 bu.	67 bu.	1.3 tns	1.35 tns	1.3 tns	1.35 tns	1.35 tns	1.4 tns

Appendix B, Table 1. (continued)

ITEM #	(SBAWW), (RB1,2,3,4), (CB)									
	B-2a		B-1b		B-2b		C-1		C-2	
	H	L	H	L	H	L	H	L	H	L
(1)	6.66									
(2)	15.28									
(6)	10.15						6.82			
(9)	2.43									
(10)	4.74		3.14		4.59		3.70		5.16	
(14)	1.84		1.49		1.79		1.80		2.10	
(15)	3.08		2.94		3.07		2.75		2.88	
(16)	3.83									
(17)	48.01	48.01	45.92	45.92	47.80	47.80	43.27	43.27	45.15	45.16
	1.35 tns	1.4 tns	1.35 tns	1.4 tns	1.35 tns	1.4 tns	1.35 tns	1.4 tns	1.35 tns	1.4 tns

Appendix B, Table 1. (continued)

ITEM #	Dry Peas (DP)									
	A-1		A-2		B-1a		B-1b		B-2	
	H	L	H	L	H	L	H	L	H	L
(1)	20.56									
(2)	0.00									
(6)	12.37				11.04	11.71	11.04	11.71	11.04	11.71
(9)	2.60									
(10)	3.44		4.89		3.86		3.99		5.32	
(14)	1.72		2.02		1.89		2.05		2.19	
(15)	3.05		3.18		3.00	3.05	3.02	3.07	3.13	3.18
(16)	3.99									
(17)	47.73	47.73	49.61	49.61	46.94	47.66	47.25	47.97	48.83	49.55
	1310 lb	1365 lb	1310 lb	1365 lb	1425 lb	1487 lb	1425 lb	1487 lb	1425 lb	1487 lb

Appendix B, Table 1 (continued)

ITEM #	(DP)					
	C-1a		C-1b		C-2	
	H	L	H	L	H	L
(1)	20.56					
(2)	0.00					
(6)	9.85	9.70	9.85	9.70	9.85	9.70
(9)	2.60					
(10)	4.31	4.30	4.44	4.43	5.89	5.88
(14)	2.06	2.05	2.22	2.21	2.52	2.51
(15)	2.95	2.94	2.98	2.96	3.11	3.09
(16)	3.99					
(17)	46.32	46.14	46.64	46.45	48.52	48.33
	1455 lb	1517 lb	1455 lb	1517 lb	1455 lb	1517 lb

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