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Evaluating the Economic & Environmental Impacts of

FARMING PRACTICES ON THE PALOUSE

Using PLANETOR™

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SOIL EROSION

The Palouse region includes over two million acres of rich agricultural land in northern Idaho and eastern Washington. The area has dune-shaped, steeply rolling hills covered with deep, silt loam soils. In some areas, slopes exceeding 40 percent are cultivated. Annual precipitation between 14 and 22 inches and soils with high water-storage capacity make this area one of the most productive dryland winter wheat areas in the nation (Steiner, 1987).

Soil erosion is possibly the greatest threat to sustainable agricultural production in the Palouse. Topsoil and soil organic matter loss impairs the soil's water-storage capacity, reduces the soil's natural fertility, and requires increased use of fertilizers to maintain yields.

Erosion's effect on crop productivity is difficult to measure because of the complexity of plant response to soil properties (Pierce, 1991). The productivity effects of soil erosion are cumulative and are often not observed until long after the damage is done. Commercial fertilizers, pesticides, and high-yielding cultivars offset productivity losses of eroded topsoil and disguise the impact of soil erosion on agricultural land (Walker and Young, 1986). For example, winter wheat yields on the Palouse have increased about ten bushels every ten years since the 1950s (Steiner, 1987), despite 25 to 75 percent of the original topsoil having been eroded from 60 percent of Palouse cropland by the mid-1970s (USDA, 1978).

Successful adoption of soil conservation practices in the Palouse depends on management skills of farmers and on the cost of implementing those practices (CAST, 1975). Soil conservation practices can increase the per-acre cost of production (Hartmans, 1996). The benefits of conservation-oriented farm management plans are often non-monetary or only realized at some future time. Farmers are reluctant to invest in soil conservation unless they are assured of future benefits (Napier and Forster, 1982). Uncertainty about costs and benefits is a major barrier to adopting conservation practices.

Farmers' perceptions of soil erosion have contributed to the number of conservation practices already being used. Most Palouse farmers employ soil conservation practices, such as reduced tillage, contour plowing, or contour strip cropping to reduce erosion (Carlson et al., 1994). Crop residues are routinely left on or near the soil surface to slow surface run-off and prevent soil particle movement. Despite these practices, soil erosion on many fields in the region still exceeds the rate at which the soil can rebuild itself.

PLANETOR™

Farmers need to evaluate the economic and environmental impacts of different conservation practices. PLANETOR™, a farm management software program developed by the Center for Farm Financial Management at the University of Minnesota, is designed to do that. It includes a whole farm budget evalua-

Table 1: Typical expected revenues, variable costs, and net income per acre for crops used in this study, 1990-1994 averages.

	Crops Used in Rotations							
	Wheat[a]	Wheat[b]	Wheat[c]	Wheat[d]	Fallow	Peas	Barley	Alf. GM
Price $/unit	$3.375/bu.	$3.375/bu.	$3.375/bu.	$3.375/bu.	$0.00	$0.0875/lb	$2.655/bu.	$79.20/ton
Revenue $/acre	$229/ac.	$229/ac.	$229/ac.	$229/ac.	$0.00	$162/ac.	$158/ac.	$119/ac.
Variable Cost $/ac.	$85/ac.	$79/ac.	$101/ac.	$87/ac.	$8 /ac.	$76/ac.	$104/ac.	$94/ac.
Net Income $/acre	$144/ac.	$149/ac.	$128/ac.	$142/ac.	($8)/ac.	$86/ac.	$54/ac.	$25/ac.

a. Wheat after Peas; b. Wheat after Summer Fallow; c. Wheat after Wheat; d. Wheat after Green Manure tor to assess economic aspects of management decisions. The program incorporates Revised Universal Soil Loss Equation (RUSLE) technology, developed by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) to estimate soil erosion. It also uses the Nitrate Leaching and Economic Analysis Package (NLEAP) Model to track the movement of nitrates (NO3) through the soil. PLANETOR™ also assesses potential movement of pesticides and phosphorus applied to crops.

The unique weather, soil, and cropping conditions of the Palouse provide an opportunity to evaluate PLANETOR™'s adaptability to site-specific conditions. The objectives of this study were:

1) To estimate changes in soil erosion using different tillage methods and conservation practices under typical Palouse farming conditions.
2) To evaluate the economics of soil erosion and/or erosion reduction from each cultivation practice.
3) To estimate the potential environmental hazard of fertilizer and pesticides leaching into ground water or being carried by runoff into surface water.

Methods

Features typical of the Palouse agricultural region were incorporated into a hypothetical farm model. Annual average rainfall was assumed to be 21 inches per year. Since approximately 98 percent of soil erosion in the Palouse occurs on soils classified as IIIe and IVe (USDA, 1978), soils typical of the high rainfall region of the Palouse were chosen with those capability classifications. These soil types were distributed over the topography of the "typical Palouse hill." The hypothetical farm was divided into 10 fields, with one soil type and set of soil conditions and properties for each field. (This was a recognized oversimplification used for this study. Under actual conditions, one field may include several soil types. Slope and organic matter content may also vary from one area of a field to another.)

Four typical rotations for the Palouse region were studied: 1) a two-year wheat-pea rotation, 2) a three-year wheat-barley-pea rotation, 3) a four-year continuous wheat-fallow rotation, and 4) a five-year wheat-pea rotation with alfalfa green manure. The wheat-pea and wheat-barley-pea rotations were examples of continuous cropping, where 100 percent of the available land was planted in marketable crops. The continuous wheat-fallow rotation, with 75 percent of available land planted in wheat, was included to study

Table 2: Changes in production costs and average soil erosion per acre for the winter wheat-pea rotation, for all tillage methods and conservation practices

	Conventional Tillage		Reduced Tillage		Minimum Tillage	
Practice	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)
No Practice	$ 0.00	0.0	$ 0.92	-14.8	$23.05	-23.3
Contour Tillage	$ 1.85	-14.0	$ 2.32	-23.0	$24.36	-27.2
Divided Slopes	$ 2.55	-15.4	$ 2.56	-23.7	$24.65	-27.6
Contour Strips	$ 9.58	-16.2	$10.12	-24.2	$34.21	-27.8

the impact of summer fallow on net income and soil erosion. The wheat-pea-alfalfa green manure rotation was used to study the impact of a green manure crop on income and soil erosion. Approximately 36 percent of the land was tied up in alfalfa for green manure. Income generated from small cuttings of alfalfa hay helped offset the cost of growing green manure.

To analyze the effects of tillage and conservation practices on income and the environment, each rotation was treated independently for three tillage methods (conventional, reduced, and minimum tillage) using four conservation practices (no conservation treatment, contour tillage, divided slopes, and contour strip-cropping). It was assumed that reducing tillage intensity would decrease production costs per acre as well as reducing soil erosion. Higher production costs and greater reductions in soil erosion were expected with progressively more management-intensive conservation practices.

Conventional tillage generally included a moldboard plow for primary tillage and other tillage operations as described by Pawson and colleagues (1961) to ensure a finely pulverized seedbed. Reduced or conservation tillage generally included a chisel plow for primary tillage. Secondary tillage operations were used to adequately prepare the seedbed while leaving at least 30 percent residue cover on the soil surface throughout the erosion season.

Minimum tillage included only those operations needed to prepare the seedbed and used a no-till drill for seeding small grain crops. Conventional tillage with no conservation practice was used as a base to compare the impact of alternative tillage and conservation practices on farm income and soil erosion.

Typical operating budgets for crops in the rotations were developed using five-year (1990-1994) average crop prices and yields gathered from the Idaho Agricultural Statistics Service for Latah County, Idaho. (Yields for crops in all rotations for this study were assumed to be constant for all tillage methods and conservation practices. Under actual farming conditions, yields may vary under different tillage practices and following various other crops in the rotation.) Input and machinery prices used in the budgets were for the northern Idaho region (Patterson et al, 1995). Fertilizer and pesticide application rates typical for the region were also used.

Results of the base budgets are presented in Table 1. The base budgets were then modified for field efficiency losses and additional purchased inputs as needed for contouring and dividing the slope.

PLANETOR™ allows the user to select site-specific climate, soil, crop, machinery, tillage, fertilizer, and pesticide information from extensive databases included in the program. Users can also customize the databases to suit individual farm operations.

Table 3: Average cost per ton of soil erosion reduced for the winter wheat-pea rotation, for all tillage methods and conservation practices.

Practice	Conventional Tillage ($/ton)	Reduced Tillage ($/ton)	Minimum Tillage ($/ton)
No Practice	$ 0.00	$ 0.06	$0.99
Contour Tillage.	$ 0.13	$ 0.10	$0.90
Divided Slope	$ 0.17	$ 0.11	$0.89
Contour Strip	$ 0.59	$ 0.42	$1.23

Table 4: Changes in production costs and average soil erosion per acre for the winter wheat-barley-pea rotation, for all tillage methods and conservation practices.

	Conventional Tillage		Reduced Tillage		Minimum Tillage	
Practice	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)
No Practice	$0.00	0.0	($1.36)	-17.8	$18.26	-23.8
Contour Tillage	$2.10	-13.8	$0.16	-23.8	$20.34	-27.4
Divided Slopes	$3.10	-15.1	$0.58	-24.9	$21.12	-27.8
Contour Strips	$11.13	-15.6	$7.47	-24.6	$31.72	-27.9

Selections used to configure PLANETOR™ to Palouse operating conditions were based on assumptions about the typical Palouse farm (Hartmans, 1996). The Pullman, Washington RUSLE site information, with the rainfall equivalent (REQ) option, was chosen for estimating the impact of winter freezing and thawing on soil erosion. A Moscow, Idaho NLEAP climate site was developed to estimate the impact of local weather conditions on nitrogen leaching.

PLANETOR™'s extensive crop databases include crop information needed for the RUSLE and NLEAP subroutines. The main database references the RUSLE crop database and the NLEAP crop database to estimate soil erosion and nitrogen leaching. Crop information specific to growing conditions in the Pacific Northwest was chosen from the databases.

Soils typical for Latah County, Idaho were selected from PLANETOR™'s Idaho soils database. Hartmans (1996) modified PLANETOR™'s machinery operations database was used to represent equipment operating conditions on hilly Palouse topography. Fertilizer and pesticide rates and application methods typically used in the Palouse were chosen from PLANETOR™'s databases of agricultural chemicals.

PLANETOR™ users may choose among several conservation practices: contouring, contour strips, several styles of terracing, tile drainage, and a category called other, which indicates no conservation support practice is used. This choice results in the highest possible P factor (P = 1.0) for use in the RUSLE calculations. Detailed information for each practice option describes soil surface roughness and the amount of soil surface cover leading into the erosion season. PLANETOR™ uses the choice of practice and the supporting details in RUSLE soil erosion calculations.

PLANETOR™ uses a rating system of HIGH, MEDIUM, and LOW to evaluate the potential environmental hazards from agricultural chemicals. Cut-off values for these ratings can be adjusted to reflect the user's perception of each potential threat to the environment.

Results

Crop Rotations

Winter Wheat-Pea Rotation Production costs for this rotation increased as tillage was reduced and as more management-intensive conservation practices were applied. Average soil erosion per acre was reduced by decreases in tillage and by increases in conservation practice intensity. Per- acre changes in production costs and soil erosion for alternative tillage methods and conservation practices were compared to conventional tillage using no conservation practice (Table 2).

For the winter wheat-pea rotation, as more management-intensive conservation

Table 5: Average cost per ton of soil erosion reduced for the winter wheat-barley-pea rotation, for all tillage methods and conservation practices.

Practice	Conventional Tillage ($/ton)	Reduced Tillage ($/ton)	Minimum Tillage ($/ton)
No Practice	$ 0.00	($0.08)	$0.77
Contour Tillage	$ 0.15	$ 0.01	$0.74
Divided Slope	$ 0.21	$ 0.02	$0.76
Contour Strip	$ 0.71	$ 0.30	$1.14

Table 6: Changes in production costs and average soil erosion per acre for the continuous wheat-fallow rotation, for all tillage methods and conservation practices.

	Conventional Tillage		Reduced Tillage		Minimum Tillage	
Practice	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)
No Practice	$ 0.00	0.0	($ 3.10)	-28.6	$28.48	-41.4
Contour Tillage	$ 1.49	-22.8	($ 0.86)	-36.9	$28.84	-43.2
Divided Slopes	$ 1.40	-25.0	($ 2.14)	-37.5	$28.61	-43.5
Contour Strips	$ 9.17	-25.8	$ 4.08	-38.0	$39.04	-43.6

practices were used, the cost per ton for reducing soil erosion generally increased (Table 3). Herbicides used to replace tillage for weed control resulted in higher input costs for the wheat-pea rotation. Higher cost for weed control overshadowed any savings from reduced fuel, equipment, and labor costs of fewer tillage operations. Costs per acre were highest for minimum tillage because of higher maintenance costs for the specialized no-till grain drill and greater herbicide expenditures.

Costs were highest for every tillage method under contour strip-cropping. This was partially due to higher machinery costs associated with field efficiency losses from maneuvering in the relatively narrow strips. Additionally, spillage and overlapping of fertilizer and herbicide applications to the strips increased the amounts of agricultural chemicals used during contour strip-cropping.

Winter Wheat-Barley-Pea Rotation Production costs for this rotation decreased with reduced tillage and increased with minimum tillage, with costs progressively increasing with more management-intensive conservation practices. Soil erosion per acre generally decreased as less tillage and more management-intensive conservation practices were used. Conventional tillage with no conservation practice was again used as a base to compare per acre changes in production costs and soil erosion for alternative tillage methods and conservation practices (Table 4).

As more management-intensive conservation practices were used, the cost per ton of reducing soil erosion increased (Table 5). Unlike the winter wheat-pea rotation, reduced tillage resulted in lower production costs compared to conventional tillage. Fuel and equipment operating cost savings were larger than the additional cost of herbicides for weed control. Minimum tillage again resulted in highest production costs of the three tillage methods, because of the cost of herbicides and high machinery maintenance costs. As with the wheat-pea rotation, production costs were considerably higher for contour strip-cropping than for other conservation practices.

Continuous Winter Wheat-Fallow Rotation Cost decreases for reduced tillage were more noticeable for the continuous wheat-fallow rotation than for previous rotations. Again, production costs generally increased with minimum tillage and more management-intensive conservation practices. Average soil erosion per acre decreased as less tillage and more intensive conservation practices were used. Per acre changes in production costs and soil erosion for alternative tillage systems and conservation practices were compared to conventional tillage using no conservation practice and are outlined in Table 6.

The average cost per ton of soil erosion reduced decreased for all conservation practices when reduced tillage was used and

Table 7: Average cost per ton of soil erosion reduced for the continuous wheat-fallow rotation, for all tillage methods and conservation support practices.

Practice	Conventional Tillage ($/ton)	Reduced Tillage ($/ton)	Minimum Tillage ($/ton)
No Practice	$ 0.00	($0.11)	$0.69
Contour Till.	$ 0.07	($0.02)	$0.67
Divided Slope	$ 0.06	($0.06)	$0.66
Contour Strip	$ 0.36	$0.11	$0.90

Table 8: Changes in production costs and average soil erosion per acre for the winter wheat-pea-alfalfa green manure rotation, for all tillage methods and conservation practices.

	Conventional Tillage		Reduced Tillage		Minimum Tillage	
Practice	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)	Cost ($/acre)	Erosion (tons/acre)
No Practice	$0.00	0.0	($1.39)	-8.4	$20.35	-10.4
Contour Tillage	$1.08	-6.5	($0.78)	-10.8	$17.62	-11.7
Divided Slopes	$1.27	-7.6	($0.45)	-11.1	$17.62	-11.9
Contour Strips	$6.86	-7.8	$5.69	-11.2	$25.77	-11.9

increased when minimum tillage was used. The cost per ton for reducing soil erosion generally increased for all tillage methods, as more progressive management-intensive conservation practices were applied (Table 7). Cost per ton for reduced soil erosion with minimum tillage was greater for the continuous wheat-fallow rotation than for the previous rotations.

Production costs were lower for reduced tillage than for conventional tillage. Reductions in operating costs for reduced tillage were greater than costs for additional herbicides. Production costs were higher for minimum tillage than for other tillage methods due to additional maintenance and herbicide costs. Costs were considerably higher for contour strip-cropping than for other conservation practices due to the cost of equipment efficiency losses and overlap/waste of agricultural chemicals.

Average per-acre changes in soil erosion were larger for the continuous wheat-fallow rotation. This was primarily due to the protection given to fallow acreage by reduced tillage and increased conservation practice.

Winter Wheat-Pea-Alfalfa Green Manure Rotation In general, production costs for the wheat-pea-alfalfa green manure rotation generally increased with the more management-intensive conservation practices. Whole farm average soil erosion per acre generally decreased as more intensive conservation practices were used. Changes in production costs and soil erosion per acre for alternative tillage and conservation practices were compared to conventional tillage using no conservation practice (Table 8).

The cost per ton for reducing soil erosion generally increased for progressively more management-intensive conservation practices (Table 9). However, for contour and divided slope practices using minimum tillage, the cost per ton for reducing soil erosion decreased for the wheat-pea-alfalfa green manure rotation.

Economic Comparison of Rotations

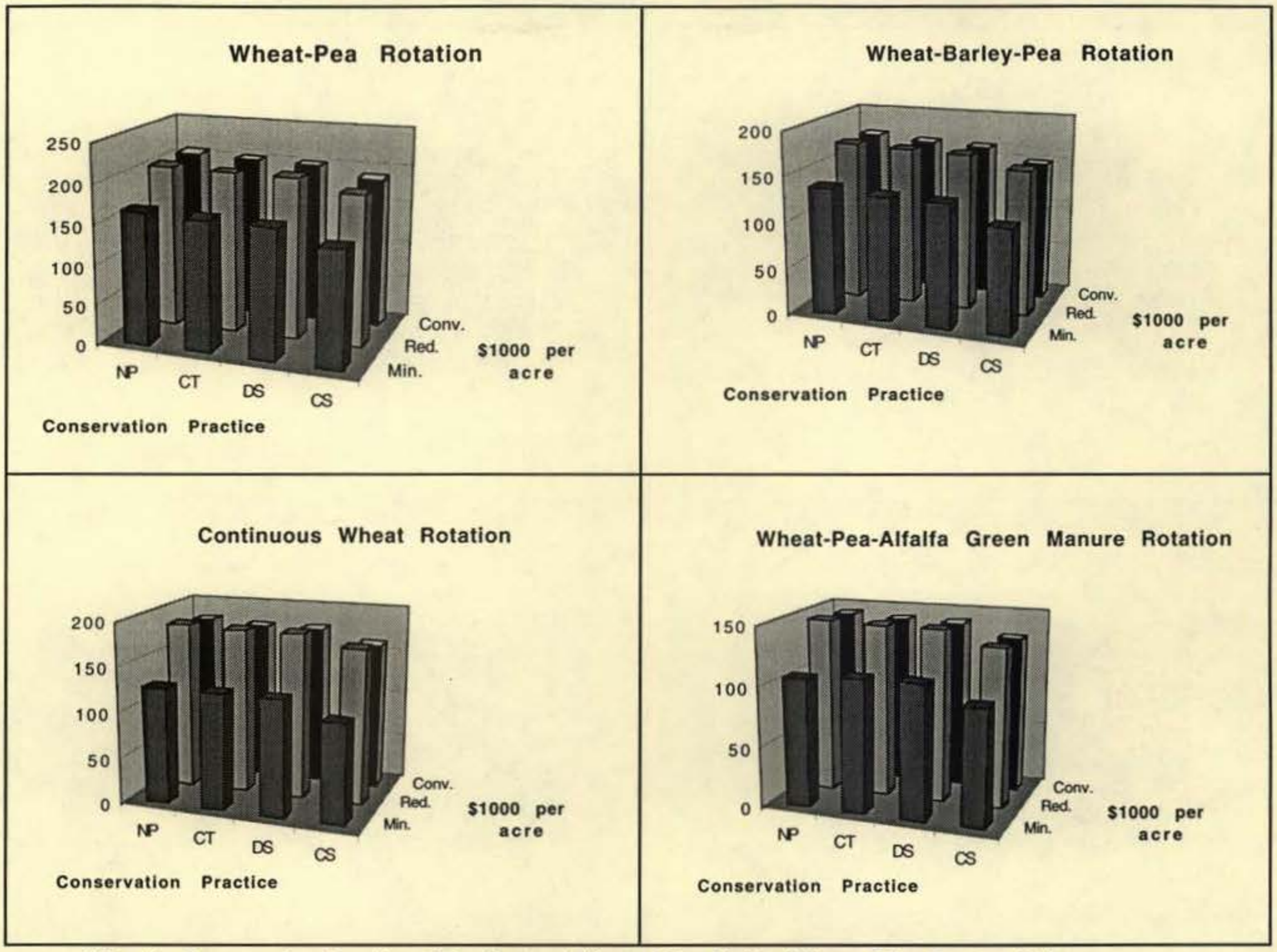
Figure 1 compares the impacts of different tillage methods and conservation practices on farm net income for each rotation. Plate 1 illustrates those impacts for the winter wheat-pea rotation. Plates 2, 3, and 4 illustrate the same impacts for the wheat-barley-pea, the continuous wheat-fallow, and the wheat-pea-alfalfa green manure rotations, respectively. For all rotations, small differences were observed when comparing the economic impacts of conventional and reduced tillage methods. Much larger differences were seen between either conventional or reduced tillage and the minimum tillage system.

It was expected that reductions in the number of tillage operations would result in higher farm net income (reduced costs) for each rotation. In general, this proved true when comparing reduced tillage to conven-

Table 9: Average cost per ton of soil erosion reduced for the winter wheat-pea-alfalfa green manure rotation, for all tillage methods and conservation practices.

Practice	Conventional Tillage ($/ton)	Reduced Tillage ($/ton)	Minimum Tillage ($/ton)
No Practice	$ 0.00	($0.17)	$ 1.96
Contour Till.	$ 0.17	($0.07)	$ 1.51
Divided Slope	$ 0.17	($0.04)	$ 1.48
Contour Strip	$ 0.88	$0.51	$ 2.17

Figure 1: Impacts of tillage method and conservation practice on farm net income for all rotations.



NP = No Conservation Practice; CT = Contour Tillage; DS = Divided Slope; CS = Contour Strip

tional tillage. However, the minimum tillage system resulted in greater production costs per acre for all rotations. This was primarily due to the cost of herbicides used to replace mechanical tillage for weed control and higher maintenance costs for specialized no-till equipment.

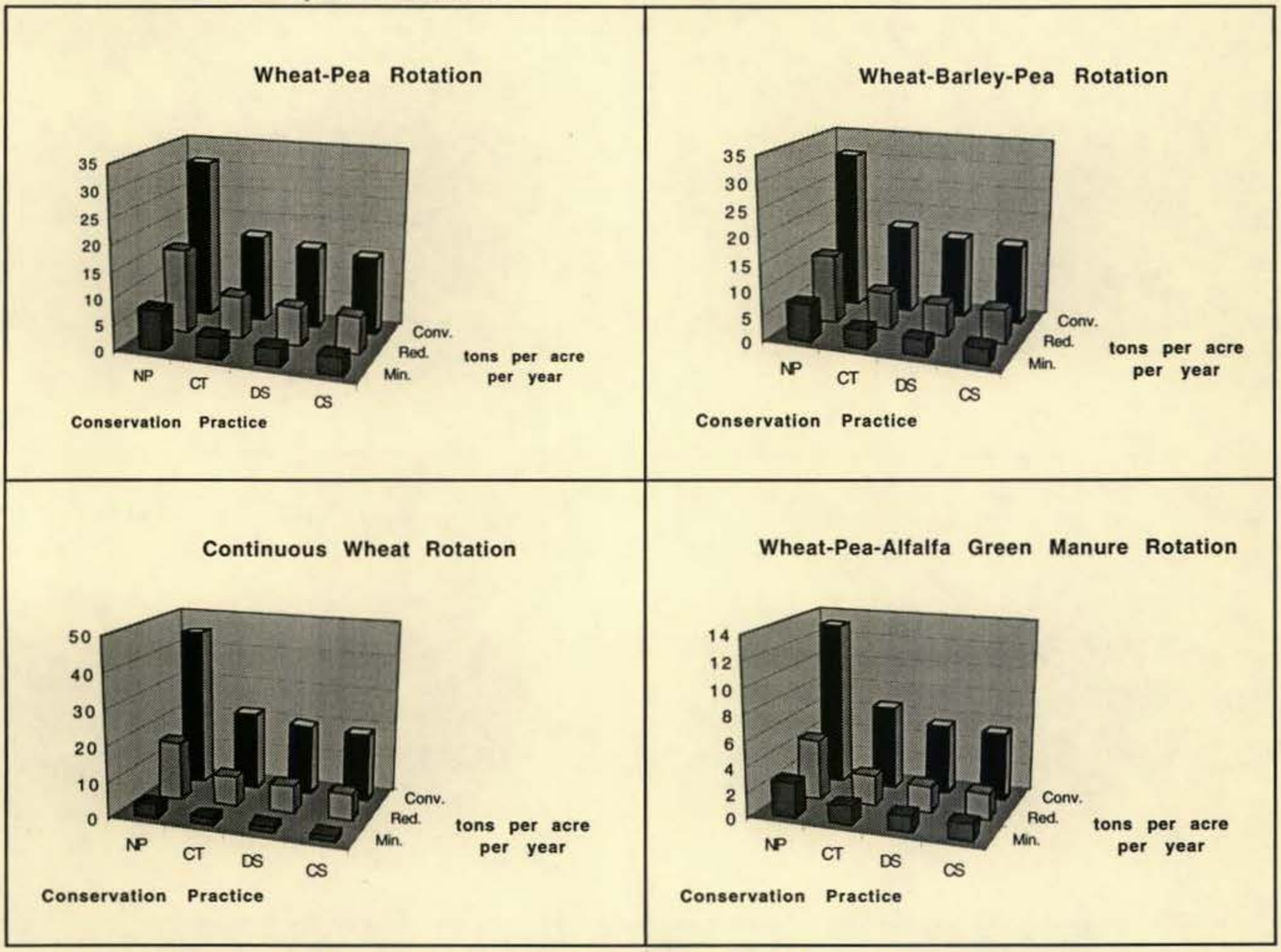
It was also expected that farm net income would decrease (costs increase) with progressively more management-intensive conservation practices. Overall, this proved to be true. Planting in narrow (50-foot) contour strips required greater management skill and was more costly than managing wider (200-foot) strips across divided slopes. Contouring required more skill and was slightly more costly than using no conservation support practice. In general, farm net income decreased with each more intensive conservation practice. This pattern was consistent for all rotations and tillage methods.

Soil Erosion Comparisons for Rotations

Figure 2 illustrates the impacts of tillage method and conservation practice on average soil erosion per acre for each rotation studied. Plate 1 depicts those impacts for the wheat-pea rotation. Plates 2, 3, and 4 illustrate the same impacts for the wheat-barley-pea rotation, the continuous wheat-fallow rotation, and the wheat-pea-alfalfa green manure rotations, respectively.

PLANETOR™ estimated average annual soil erosion per acre for the four rotations. Crops used in the rotation appeared to have

Figure 2: Impacts of tillage method and conservation practice on whole farm average annual soil erosion, for all rotations.

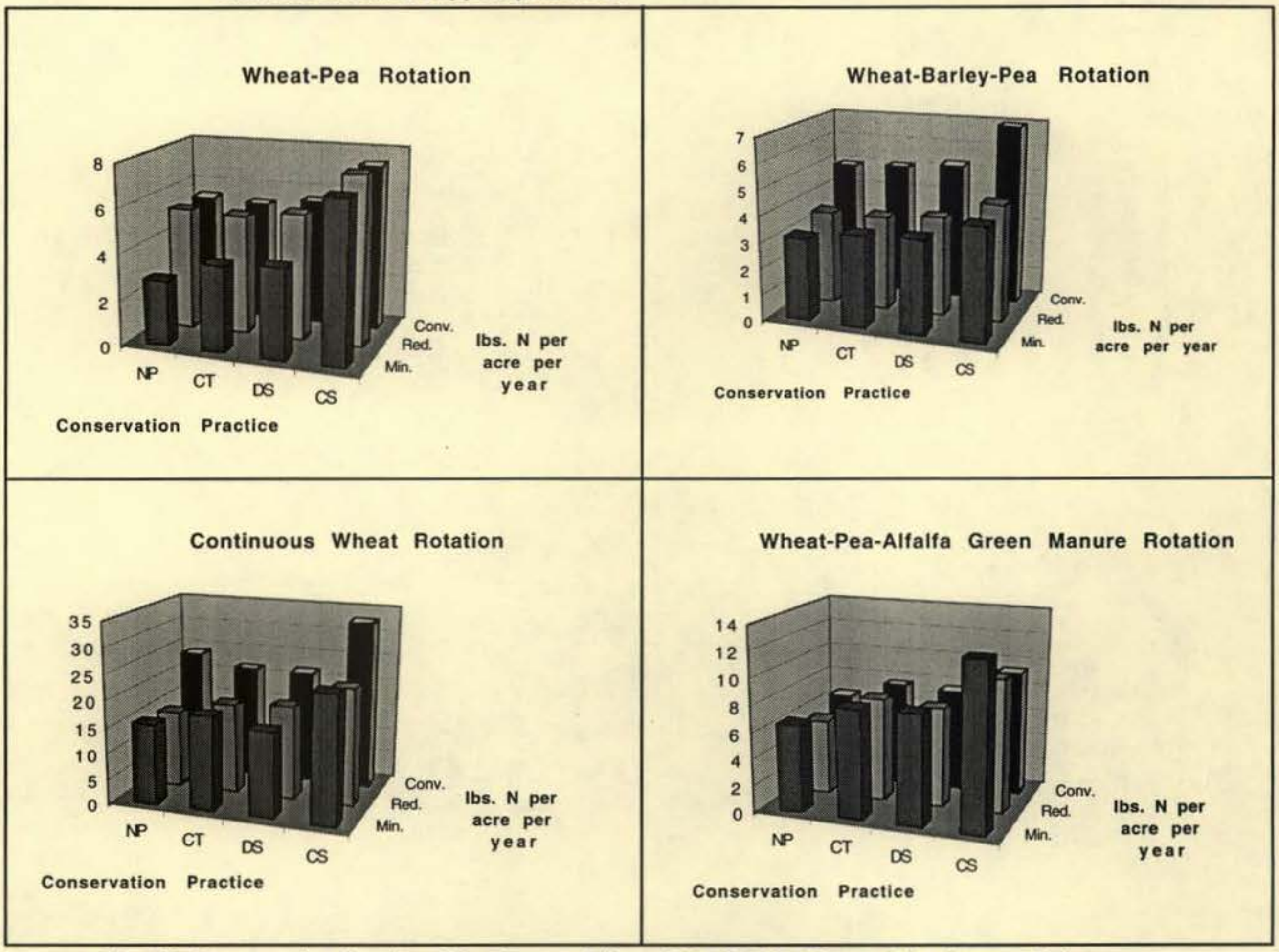


NP = No Conservation Practice; CT = Contour Tillage; DS = Divided Slope; CS = Contour Strip

an impact on average soil erosion per acre. For example, whole farm average soil erosion per acre was highest for the continuous wheat-fallow rotation, which included summer fallow on 25 percent of the total acres. Average soil erosion per acre was lowest for the wheat-pea-alfalfa green manure rotation, with 25 percent of total acres completely undisturbed during one winter erosion season.

As expected, average soil erosion per acre decreased with decreased tillage intensity. Reduced or conservation tillage prevented approximately 60 percent of the soil loss normally associated with conventional tillage. With minimum tillage, soil erosion per acre was approximately 20 percent of that normally associated with conventional tillage. Average per acre soil erosion decreased with each progressively more management-intensive conservation practice. Contour tillage decreased average soil erosion per acre by about 50 percent more than tillage methods using no conservation practice. The divided slope practice resulted in further decreases in average soil erosion per acre, with narrower strips providing greater reductions in soil loss than wider strips.

Figure 3. Comparison of mineral nitrogen leached (NL) from each rotation for all tillage methods and conservation support practices.



NP = No Conservation Practice; CT = Contour Tillage; DS = Divided Slope; CS = Contour Strip

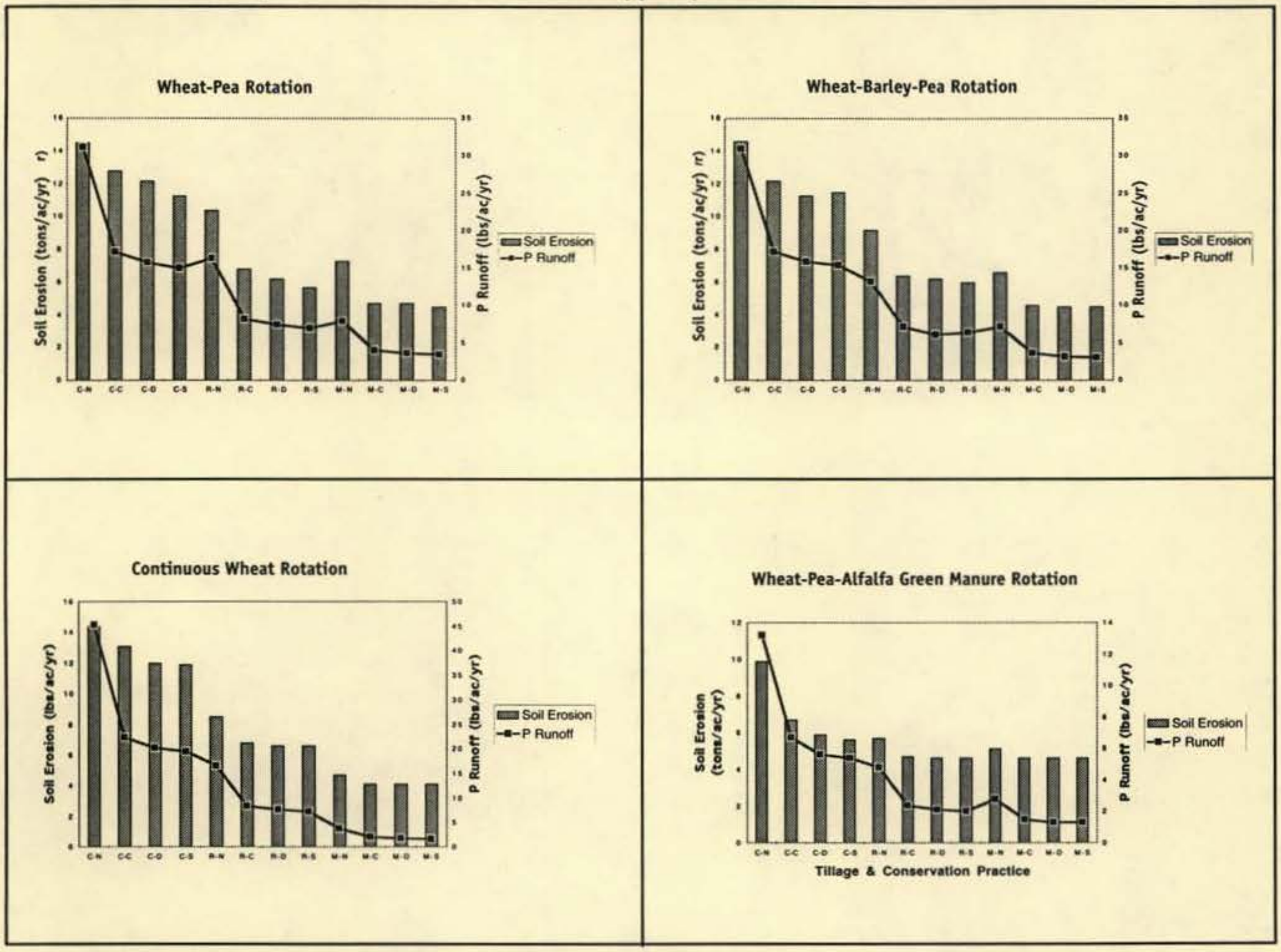
Fertilizer Impacts

Comparison of Nitrogen Leaching from Rotations PLANETOR™ evaluated the potential for nitrogen leaching for each rotation by tillage method and conservation practice. Figure 3 compares whole farm average nitrogen leached (NL) per acre for each rotation. Plate 1 illustrates the impact of tillage method and conservation practice on nitrogen leaching for the winter wheat-pea rotation. Plates 2, 3, and 4 depict the same impacts for the winter wheat-barley-pea rotation, the continuous winter wheat-fallow rotation, and the winter wheat-pea-alfalfa green manure rotation, respectively.

In general, the potential for nitrogen leaching from any rotation was greatest with the minimum tillage system. More commercial fertilizer was usually applied with minimum tillage because soil nitrogen and microbes in soil organic matter were occupied breaking down residue from previous cropping. PLANETOR™ also showed that nitrogen leaching potential was greatest when contour strip-cropping was used as a conservation practice. This could be a misrepresentation, since extra nitrogen values were added in the PLANETOR™ model to economically account for fertilizer wasted while maneuvering in the field. Also, soil erosion losses were usually lowest under contour stripping. Therefore, more of the available nitrogen, commercial or organic, stayed on the field instead of being carried away by surface runoff.

Average nitrogen available for leaching (NAL) per acre for all rotations far exceeded the amount of commercial nitrogen applied.

Figure 4: Comparison of soil erosion and phosphorus runoff for each rotation studied, for all tillage methods and conservation support practices.



C = Conventional Tillage; R = Reduced Tillage; M = Minimum Tillage.
-N = No Conservation Practice; -C = Contour Tillage; -D = Divided Slopes;-S = Contour Strips.

Note: Soil erosion was measured in tons per acre while phosphorus runoff was measured in pounds per acre. To illustrate soil erosion and phosphorus runoff on the same graph, the values for soil erosion and phosphorus runoff were scaled into similar units. Figure 4 uses this relative scaling to compare PLANETOR™'s phosphorus runoff estimates (lb/ac) to soil erosion estimates (tons/ac) for each rotation.

Most NAL was used by crops over the growing season. Some NAL (especially from nitrogen applied in the fall to winter wheat) would be carried off the field by surface runoff during the erosion process. PLANETOR™ indicated that some NAL could potentially be leached away from the cropping system. However, the amount of nitrogen that could actually leach (NL) from each rotation was very small compared to the NAL.

Phosphorus Runoff from the Rotation Phosphorus chemically bonds to soil particles and tends to be carried off the field with eroded sediments by surface runoff. Soil erosion estimates generated by the RUSLE subroutine, organic phosphorus in the soil, and the amount added as fertilizer were all used by PLANETOR™ to determine the amount of phosphorus likely to be carried away with runoff. As soil erosion decreased for each rotation, the phosphorus carried from each field with surface runoff also decreased.

Figure 4 shows the relationship between soil erosion per acre and PLANETOR™'s phosphorus run-off potential for each rotation. Plate 1 shows this comparison for different treatments of the winter wheat-pea rotation. Plates 2, 3, and 4 illustrate the same comparison for the winter wheat-barley-pea rotation, the continuous wheat-fallow rotation, and the wheat-pea-alfalfa green manure rotation, respectively.

Table 10: Environmental hazards of pesticides used for all rotations.

Pesticide	Rotation[a]	Crop[b]	Leaching Potential Rating	Runoff Potential Rating	Pesticide Toxicity Rating
Banvel	3	wht	HIGH	HIGH	MEDIUM
Bronate	2	bar	LOW	LOW	MEDIUM
Buctril	all	wht	HIGH	HIGH	MEDIUM
Buctril	2	bar	LOW	HIGH	MEDIUM
Far-go	1,2,4	peas	HIGH	HIGH	LOW
Far-go	3	bar	HIGH	HIGH	LOW
Far-go	4	alf	HIGH	HIGH	LOW
Harmony Extra	all	wht	HIGH	HIGH	LOW
Harmony Extra	2	bar	HIGH	HIGH	LOW
Hoelon 3EC	1,2,4	wht	HIGH	HIGH	HIGH
Hoelon 3EC	3	wht	HIGH	MEDIUM	HIGH
Hoelon 3EC	2	bar	MEDIUM	HIGH	HIGH
Lexone DF	1,2,4	peas	MEDIUM	HIGH	LOW
Poast	4	alf	LOW	LOW	MEDIUM
Roundup	1	peas	HIGH	HIGH	MEDIUM
Roundup	2,4	peas	LOW	HIGH	MEDIUM
Roundup	3	fal	HIGH	HIGH	MEDIUM
Roundup	2	bar	LOW	HIGH	MEDIUM
Roundup	4	alfGM	LOW	HIGH	MEDIUM
Sonalan EC	1,2,4	peas	MEDIUM	HIGH	MEDIUM
Surfactant	all	wht	no data	no data	no data
Vitavax	3	wht	HIGH	HIGH	LOW

a. 1 = Winter Wheat-Pea Rotation; 2 = Winter Wheat-Barley-Pea Rotation; 3 = Continuous Wheat Rotation; 4 = Winter Wheat-Pea-Alfalfa Green Manure Rotation.

b. wht = Wheat; bar = Barley; alf = Establishment Year Alfalfa; peas = Peas; alfGM = Alfalfa Green Manure; fal = Summer Fallow.

Pesticide Movement from Rotations

Using chemical properties and site-specific environmental conditions, PLANETOR™ computes an index and rates each pesticide, describing its leaching or runoff potential, and relative toxicity. PLANETOR™'s pesticide ratings used in this study are listed in Table 10.

Conclusions

Continuous cropping increased farm net income while reducing soil erosion. Income was higher for rotations where 100 percent of the available land was utilized and gross returns per acre for all crops in all the rotations were greater than production costs. The winter wheat-pea rotation and the winter wheat-barley-pea rotation both resulted in higher net income than either the continuous wheat-fallow or the wheat-pea-alfalfa green manure rotations. The continuous wheat rotation included summer fallow, which generated no income. The wheat-pea-alfalfa green manure rotation included establishment-year alfalfa where production costs exceeded gross revenue.

One expectation of this study was that as the number of tillage operations decreased, production costs per acre would decrease and farm net income would increase. Reduced tillage resulted in higher net farm income for most of the rotations studied. Compared to conventional tillage, reduced tillage resulted in an average decrease of about 3 percent in production costs for all rotations except the wheat-pea rotation. For that rotation, production costs for reduced tillage were 0.6 percent higher than for conventional tillage due to added costs for chemical weed control. This was also true for the minimum tillage system for all rotations. Cost savings from fewer tillage operations were over-shadowed by large increases in herbicide costs. Costs of production per acre for minimum tillage increased by approximately 28 percent over costs for conventional tillage.

Per acre production costs generally increased as progressively more management-intensive conservation practices were applied. For example, contour tillage increased production costs by about 2 percent for all tillage methods using no conservation practice. Divided slopes increased production costs by an average of 2 percent over the cost of production using no conservation practice. Planting in contour strips resulted in an average increase in production costs of 11 percent over no conservation practice.

The greatest reductions in soil erosion were seen between conventional tillage and reduced tillage for all conservation practices. Compared to conventional tillage, soil erosion was reduced by an average of 59 percent for all rotations using reduced tillage. Minimum tillage reduced average soil erosion per acre by 81 percent compared to conventional tillage, for all rotations.

Different conservation practices also reduced soil erosion. For all rotations and tillage methods, contour tillage decreased soil erosion by an average of 48 percent over no conservation practice. Dividing slopes reduced soil erosion by an average 54 percent, and contour strip-cropping reduced soil erosion by 56 percent, compared to no conservation practice.

PLANETOR™ rated the potential for environmental damage from the agricultural chemicals used in the study. The potential hazard of nitrogen leaching into groundwater was rated LOW for all rotations. PLANETOR™'s phosphorus runoff evaluation was also LOW for the rotations. Most of the herbicides used in this study were rated HIGH for potential contamination of both ground and surface water. The relative toxicity of these chemicals generally ranged from LOW to MEDIUM.

PLANETOR™ provided relatively accurate results when evaluating the economic and environmental impacts of cropping practices in the Palouse region. Overall, it confirmed the expectation that as tillage was reduced, production costs per acre would decrease. It further showed that as conservation practices increased in management intensity, production costs increased as well. It also accurately predicted the direction of changes in production costs caused by changes in farming practices. The magnitude of those cost changes would be highly dependent on farm-specific data.

PLANETOR™'s soil erosion estimates were generally higher than those reported by Pawson and colleagues (1961) and other reports on erosion in the Palouse (Steiner, 1987). This overestimation was partially due to a programming error in PLANETOR™ version 1.02 (Richardson, 1995) and partially inherent in RUSLE methodology (Busacca et al., 1993). Since PLANETOR™ uses its own soil erosion estimates to predict nitrogen leaching, phosphorus runoff, and the movement of pesticides, these estimates may also be overstated in this study. However, its environmental impact estimates do identify problem areas within a farming system.

PLANETOR™'s output is highly dependent on user information and, therefore, does not generate a "standard" solution for other farms or regions. It does not predict with 100 percent accuracy exact changes in costs or environmental impacts from alternative farm management practices. However, it does provide an excellent illustration of the **relative** effects of different farm management decisions on farm income and on the environment. The program identifies **potential** sources of environmental pollutants in the farming system. For a farmer attempting to determine the effects of different management strategies, PLANETOR™ is an excellent tool that can be used for farm management planning under typical Palouse conditions.

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