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## SOIL EROSION, INTERTEMPORAL PROFIT, AND THE SOIL CONSERVATION DECISION

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### Abstract

This study developed an intertemporal profit function to determine optimal conservation adoption strategies under alternative scenarios with respect to crop prices, relative yields, discount rates, and other assumptions. Special emphasis was placed on determining from the analysis when the switchover from conventional to soil-conserving practices should take place. Technological change was incorporated by allowing crop yields to vary over time. Our analysis thus provides a new, more precise measurement of the cumulative net benefit differential. The optimal period for switchover from conventional to soil-conserving practices was found to vary depending on the assumptions made about corn prices and discount rates. Empirical results were based on an erosion damage function (EDF) for Western Kentucky corn production.

*Key words:* soil conservation, technical change, benefit/cost analysis, intertemporal decisionmaking, technology, adoption, no-till.

The T-value criterion for evaluating damage due to soil erosion may overprotect a number of soils, leading to higher costs for current crop production and reduced income for some farmers over the long run (Sharp and Bromley). Other conservationists have argued that the T value may be too high to preserve long-term soil productivity (Johnson). If the T value is too high, it would tend to underprotect, rather than overprotect, soil resources. An economic analysis of damages that occur over time due to soil erosion and net benefits from the adoption of soil-conserving practices could provide a more useful basis for decisionmaking about conservation practices and lead to greater net farm incomes in

the long run (Burt; Walker; Crosson and Stout).

Walker introduced an erosion damage function based on a crop yield, soil depth (Y-D) function. Walker compared the net benefits from conservation practices adopted in year  $t$  and continuing in subsequent years with the net benefits from using conventional (non-soil-conserving) practices in year  $t$  and switching to conservation practices in subsequent years. Walker's analysis did not account for net benefits from the use of conventional tillage in years prior to  $t$ , nor did it permit the farmer to delay the adoption of conservation tillage for more than one year, even if a delay was economically justified. In determining when conservation practices should be implemented, an analysis of net benefits may indicate that a delay in adoption of more than one year is warranted. Thus, the erosion damage function should account for net benefits obtained from delaying adoption and continuing to use conventional practices. Furthermore, if the year in which the switchover from conventional to soil-conserving practices is to be determined from the analysis, then the additional net benefits from continuing to use conventional practices prior to switchover must be measured.

The objective of this study is to develop and apply an intertemporal profit function to determine optimal conservation adoption strategies under alternative scenarios with respect to crop prices, relative yields, discount rates, and other assumptions. Special emphasis is placed on determining from the analysis when the switchover from conventional to soil-conserving practices should take place. The determination of when the switchover should take place is based on a net benefit criterion and explicitly accounts for the net benefits obtained from delaying adoption of soil-conserving practices and continuing to use con-

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Appreciation is expressed to Richard Ready and the anonymous reviewers for helpful comments on an earlier draft of this manuscript. Journal Paper number 89-1-181 of the Kentucky Agricultural Experiment Station.

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ventional practices for more than one year.

Thus, our analysis compares net benefits obtained when conservation practices are adopted in period  $t$  and in subsequent years ( $t+1, t+2, \dots, T$ ) with the net benefits obtained when there is a delay of one or more years in the adoption of the conservation practice. Technological change is also incorporated into the model by allowing crop yields to vary over time. Our analysis thus provides a new, more precise measurement of the cumulative net benefit differential. The optimal period for switchover from conventional to soil-conserving practices also varies depending on the assumptions made about corn prices and discount rates. Empirical results are based on an estimated Y-D function and an erosion damage function (EDF) for Western Kentucky corn production (Pagoulatos et al.).

### YIELD DIFFERENTIALS AND THE TECHNOLOGICAL CHANGE MODEL

Young et al. reported an interaction between technological progress and soil depth for wheat cropland in the Palouse. Results were obtained from two Y-D functions estimated using data sets on soil depth and yield that were collected from two different periods, 1952-1953 and 1970-1974 (Taylor). If there is an improvement in technology in period  $t+1$  relative to period  $t$ , then the yield at a given soil depth (according to the Y-D function) must be adjusted upward by the amount of the productivity change.

At soil depth  $x_t$ , the crop yield (per acre) from the Y-D function at time  $t$  is  $y(t|x_t)$ . With improved technology at time  $t+1$  but with a reduced soil depth  $x_{t+1}$  ( $x_{t+1} < x_t$ ), the yield is  $y(t+1|x_{t+1})$  which may not always be less than

$y(t|x_t)$  even if  $x_{t+1} < x_t$ . This is expressed as:

$$(1) \quad y(t+1|x_{t+1}) = [y(t|x_t) - \Delta y(t|x_t)] + \Delta y(t+1),$$

where

$y(t+1|x_{t+1})$  = the adjusted yield level at time (technology)  $t+1$ , and soil depth  $x_{t+1}$ ;

$y(t|x_t)$  = the yield level at time  $t$  (technology  $t$ , or according to the estimated Y-D function) and at soil depth  $x_t$ ; and

$\Delta y(t+1)$  = the amount of yield improvement (adjustment) due to technological change in the period  $t+1$ .

These concepts are also illustrated in Figure 1. To measure  $\Delta y(t+1)$ , a productivity-trend (P-T) function relevant to conventional and conservation practices is needed. The P-T function is  $g(t)$ , a function which links  $t$  and  $y(t|x_t)$ , where  $t$  is a time trend representing technological change. The output-enhancing impacts of technical change are assumed to diminish over time. Therefore, the productivity trend,  $g(t)$ , was assumed to increase at a decreasing rate, and therefore  $\partial g/\partial t > 0$  and  $\partial^2 g/\partial t^2 < 0$ . The measure of yield improvement between period  $t$  and period  $t+1$  is defined as  $m_{t+1} = (y(t+1|x_{t+1})/y(t|x_t)) \cdot 100$ . This measure is a multiplicative shift factor (uniform for all soil-depth levels) for the Y-D function bounded by zero and one. The assumption of a uniform, bounded, multiplicative shift factor is consistent with agronomic principles (Young et al.). Therefore, the adjusted yield level for each successive soil depth ( $x_{t+i}$ ,  $i > 1$ ) from production period  $t$  to production period  $t+1$ , is  $y(t+1|x_{t+i}) = (1+m_{t+1}) y(t|x_{t+i})$ , where  $x_{t+i} < x_t$  due to erosion.

The measurement of the productivity change

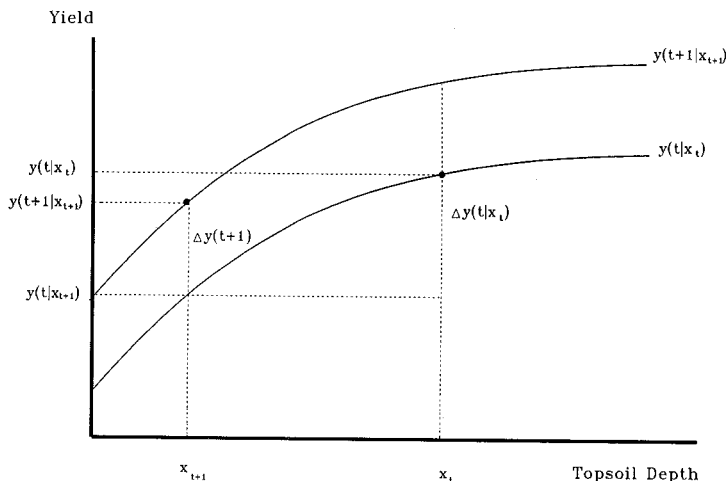


Figure 1. Yield Topsoil-Depth Function.

over time uses the P-T function. A P-T function may be estimated using either the total productivity index (TPI) method or the average yield per acre (AYPA) method. Growth in output due to technical change can be partitioned into a neutral part (pure productivity efficiency improvement) and a non-neutral part which may come from either an increase in the quantity or a change in the quality of inputs or structural change in the industry (Solow; Griliches; and Lingard and Rayner). The TPI can be obtained from factor shares (assuming competitive equilibrium) based on the Tornqvist-Theil index (Ball) and measures the impact of pure efficiency improvement.

The productivity trend for corn production under conventional and conservation practices was then assumed to follow the same path as described by the estimated P-T function. The productivity trend ( $g_t$ ) was measured by the Tornqvist-Theil index (Ball, Table 10). The P-T function, which represents the productivity trend for U.S. agriculture, is:

$$(2) \ln g_t = -0.59 + 0.016 t + 0.028$$

$$(0.02) (0.001) (0.015)$$

$\ln t$ ,  $R^2 = 0.98$  with standard errors in parentheses.

Multiplicative shift factors  $m_t$  (uniform for all soil-depths) were estimated for each year. The year 1979 was the base period for which the function was estimated. The productivity change over time (1979–2008) decreases at a decreasing rate. For example, in 1979 the productivity improvement was 1.74 percent, and this improvement was estimated at 1.71 percent and 1.70 percent in 1989 and 1999, respectively.

Equation (2) represents both conventional and conservation practices. The output (corn) price and production costs were measured in constant real dollars. Cost differentials between conventional and conservation practices were measured in real dollars (Shurley et al.). Initially, a discount rate of 4 percent (constant over the 30-year period) and a corn price of \$2.75 per bushel were assumed.

Research in Kentucky, Maryland, and Virginia found that conventional tillage produces higher yields than no-till at low nitrogen application rates, but no-till usually produces higher yields than conventional tillage at high rates of nitrogen application (Frye and Phillips). For example, agronomic data indicate that with 150 lbs. of applied nitrogen per acre, conventional till yields 15.9 percent less than no-till on Crider silt loam, about two per-

cent lower on Maury silt loam and Allegheny loam, but yields approximately the same on Tilsit silt loam (Phillips et al.; Maglaby et al.). On average, no-till with 150 lbs. nitrogen fertilizer produces higher corn yields than conventional cultivation practices in Kentucky. Moreover, conservation practices can save fuel as well as keep the soil from eroding (King).

Mueller et al. reported approximately one percent lower production costs for corn under no-till than under conventional tillage, but Epplin et al. found that operating costs were approximately four percent higher for conservation tillage than for conventional tillage. In 1985, the expected variable cost for corn production in Kentucky was \$175 per acre for conventional tillage and \$192 per acre for no-till or about 9.9 percent higher for no-till (Shurley et al.). The Kentucky Special Resource Study (USDA) also reported higher costs for no-till than for conventional tillage.

This study assumed higher costs under the conservation practices, based on the budgets by Shurley et al. No-till requires a specialized or modified planter (USDA). No-till adoption thus requires additional investment. Interest and depreciation charges for making this investment were included as a part of total costs of adoption of no till.

### DEVELOPMENT OF THE INTERTEMPORAL PROFIT FUNCTION

Suppose an individual farmer in period  $t-1$  employed a conventional (erosive) production practice using technology available in  $t-1$ . The farm is endowed with soil depth  $x_{t-1}$  at the beginning of the production period. The (minimum) cost incurred is  $c(t-1|x_{t-1})$ , and the return is  $py(t-1|x_{t-1})$ , where  $p$  is the price of corn. For production in the current period  $t$ , the farmer chooses either conventional (erosive) or conservation (no-till) production. The farmer might continue to use conventional practices for at least one more year in order to maximize the difference between expected returns and the production cost. This choice (call it option A) is an intertemporal profit function:

$$(3) \Pi_A = \sum_{i=0}^n [py(t+i|x_{t+i}) - c(t+i|x_{t+i})] (1+r)^{-i} + \sum_{m=0}^{T-n} [py(t+n+m|x_{t+n+m})^B - c(t+n+m|x_{t+n+m})^B] (1+r)^{-(n+m)},$$

where:

$\Pi_A$  = the present value of intertemporal net revenue for option A at a discount rate  $r$ ;

$p$  = output (corn) price;

- y = output quantity (bu./acre), and a function of technology and soil depth;
- c = optimal cost which depends on technology and soil depth; and
- B = conservation practices.

Equation (3) represents at least one year (or possibly n years,  $n \geq 1$ ) of conventional (erosive) practices followed by the adoption of conservation (no-till) practices for the remaining years of the planning horizon. The adoption of no-till is at least one-year delayed. For example,  $y(t|x_t)$  implies that the measured yield is dependent upon the technology used in the period t and soil depth that exists at the beginning of period t;  $y(t|x_t)$  applies to conventional practices;  $y(t|x_t)^B$  applies to conservation practices;  $c(t|x_t)$  applies to conventional practices; and  $c(t|x_t)^B$  applies to conservation practices (for  $i = 1, 2, \dots, n-1; m = 0, 1, 2, \dots, T-n; n \geq 1$ ).

Alternatively, the farmer might choose to immediately adopt no-till (call this option B). The corresponding intertemporal-profit function is:

$$(4) \Pi_B = \sum_{i=0}^T [p y(t+i|x_t)^B - c(t+i|x_t)^B] (1+r)^{-i},$$

where  $\Pi_B$  = the present value of net revenue stream for option B at a discount rate r, and other variables are as previously defined.

Equation (4) represents the present value of the net revenue stream for the conservation practice adopted without delay for all years of the time horizon. Notice that the soil depth in each production period remained unchanged at the original level  $x_t (= x_{t+1} = \dots = x_{t+T})$  once the conservation practice was adopted since erosion is assumed to continue at the regenerative rate (5 tons/acre/year) with no-till.

The decisionmaking process involves more than choosing between options A and B as suggested by equations (3) and (4). The farmer must not only decide if no-till should be implemented, but also when within the time horizon implementation should take place. The decision depends upon a comparison of net benefits from employing conventional practices for at least one more period with net benefits when erosion-induced productivity losses are avoided by adopting the conservation practice immediately. If net benefits from delaying adoption are larger than the measured erosion-induced productivity loss from implementing no-till immediately, then there is incentive for the farmer to postpone the no-till adoption.

The erosion damage function measures the reduction in net returns due to mining the soil with erosive practices for one or more periods. The erosion damage function is the difference between equations (4) and (3). Equation (3) represents a strategy consisting of n periods under conventional practices, followed by a sequence of conservation practices starting from time  $t+n+1$  to time T, where  $n \geq 1$ . In equation (4), conservation practices continue from period t until the end of the time horizon (T). The erosion damage function assuming an n-year delay in the adoption of no-till is:

$$(5) \theta_w = - \sum_{i=0}^{n-1} \{ [p y(t+i|x_{t+i}) - p y(t+i|x_t)^B] + [c(t+i|x_t) - c(t+i|x_{t+i})^B] \} (1+r)^{-i} - \sum_{m=0}^{T-n} \{ [p y(t+n+m|x_{t+n})^B - p y(t+n+m|x_t)^B] + [c(t+n+m|x_t)^B - c(t+n+m|x_{t+n})^B] \} (1+r)^{-(n+m)}.$$

The term  $\{p y(t|x_t) - p y(t|x_t)^B\}$  represents the value of the yield differential between the adopted conventional practice (in option A) and the conservation practice (in option B) in period  $i = 0$  and at soil depth  $x_t$ . Hence, this term measures part of the conventional tillage advantage over the conservation tillage. The dollar value can vary depending upon revenue generated from each practice. The term  $\{c(t|x_t) - c(t|x_t)^B\}$  is the cost differential for no-till relative to conventional practices in period  $i = 0$ .

The term  $p y(t+n+m|x_{t+n})^B - p y(t+n+m|x_t)^B$  is the value of yield differential from a change in soil depth from period t to period  $t+n$ . The discounted value of these terms is the present value of erosion-induced productivity loss (Walker and Young) over the periods T-n. It is a partial measure of the reduction in the value of the cropland due to a loss in soil depth, following an n-year ( $n \geq 1$ ) delay in no-till adoption.

As n becomes larger, the cost differential  $c(t+n+m|x_t)^B - c(t+n+m, x_{t+n})^B$  increases. Walker assumed that the cost differential was negligible for two different soil depths,  $x_t$  and  $x_{t+1}$ , under conservation practices. Therefore,  $c(t+n+m|x_t)^B$  was assumed equal to  $c(t+n+m|x_{t+n})^B$ . In each time period, the farmer incurs the same cost regardless of the soil depth and makes no attempt to offset nutrient losses inherent in the loss of soil by applying fertilizer. In addition, no extra energy is assumed to be required following an erosive tillage practice applied during earlier periods

within the time horizon.

When the option is to delay adoption of no-till by one year, both  $[py(t+ilx_{t+1})-py(t+ilx_t)^B]$  and  $[c(t+ilx_t)^B-c(t+ilx_{t+1})]$  are zero. When  $n$  is greater than one,  $c(t+n+mlx_t)^B-c(t+n+mlx_{t+n})^B$  need not be calculated. The erosion damage function is sensitive to changes in any of its arguments. Certain terms will not appear when only variable costs are of concern, but must appear when specific capital investments (such as the purchase of a no-till planter) are considered. Moreover, the net present value concept discounts the net cash flow. Consequently, varying the debt repayment period will lead to new values for the erosion damage function. Hence, in calculating the erosion

damage function, the time path for debt repayment must also be determined.

### ALTERNATIVE EMPIRICAL SCENARIOS

Values for the erosion damage function were calculated for corn with a soil depth to the fragipan varying from 60 to 35 cm. (Table 1). An average soil loss of 34.25 metric tons per hectare per year for conventional tillage, a (real) discount rate of 4 percent, and a no-till/conventional yield ratio ( $y_B/y_A$ ) of 1.03 was assumed (i.e., no-till produces 3 percent higher yields than conventional tillage). Under this set of assumptions, only on cropland with a 60 cm soil depth to the fragipan is it advanta-

TABLE 1. EROSION DAMAGE FUNCTION (EDF) VALUES, WESTERN KENTUCKY, UNDER VARIOUS ASSUMPTIONS<sup>a</sup>

Initial soil depth cm	Corn price \$/bu.	Years delay	New planter	NPV of conventional tillage advantage (a)	NPV of erosion-induced productivity loss (b)	EDF value (a-b)
Various soil depths, no new planter:						
60.0	\$2.75	1	no	\$ 7.00	\$ 6.38	\$ 0.62
57.5	2.75	1	no	7.09	8.15	-1.06
55.0	2.75	1	no	7.19	10.40	-3.21
52.5	2.75	1	no	7.33	13.31	-5.98
50.0	2.75	1	no	7.51	17.02	-9.51
45.0	2.75	1	no	8.02	27.74	-19.72
35.0	2.75	1	no	10.22	73.90	-63.68
Various soil depths, new planter:						
60.0	2.75	1	yes	14.20	10.61	3.59
57.5	2.75	1	yes	14.29	12.37	1.92
55.0	2.75	1	yes	14.40	14.63	-0.23
52.5	2.75	1	yes	14.53	17.53	-3.00
50.0	2.75	1	yes	14.71	21.24	-6.53
45.0	2.75	1	yes	15.22	31.97	-16.75
35.0	2.75	1	yes	17.43	78.12	-60.69
Delayed adoption of no-till:						
60.0	2.75	1	no	7.00	6.38	0.62
60.0	2.75	2	no	13.27	12.31	0.96
60.0	2.75	3	no	18.85	17.89	0.96
60.0	2.75	4	no	23.74	23.00	0.74
60.0	2.75	5	no	27.98	27.70	0.28
60.0	2.75	6	no	31.59	32.13	-0.54
60.0	2.75	7	no	34.59	36.10	-1.51
60.0	2.75	8	no	36.99	39.10	-2.11
Various corn prices:						
60.0	2.25	1	no	8.87	5.23	3.64
60.0	2.50	1	no	7.40	5.80	1.60
60.0	2.75	1	no	7.00	6.38	0.62
60.0	3.00	1	no	6.07	6.97	-0.90
60.0	3.25	1	no	5.13	7.55	-2.42

<sup>a</sup> A discount rate of 4 percent, a soil loss of 34.25 metric tons/hectare/year, and a yield ratio ( $y_B/y_A$ ) of 1.03 at the beginning of period  $t$  were assumed.

TABLE 2. EROSION-DAMAGE FUNCTION VALUES, WESTERN KENTUCKY, AT VARYING INTEREST RATES<sup>a</sup>

$y_B/y_A$	New Planter	discount rate		
		4 percent	6 percent \$/Acre	10 percent
1.020	no	4.11	5.48	7.14
1.030	no	0.62	2.00	3.68
1.035	no	-1.13	0.26	1.95
1.040	no	-2.87	-1.47	0.22
1.050	no	-6.36	-4.95	-3.24
1.020	yes	7.09	7.76	9.04
1.030	yes	3.59	4.28	5.58
1.040	yes	0.11	0.81	2.12
1.050	yes	-3.38	-2.67	-1.34
1.055	yes	-5.13	-4.41	-3.07

<sup>a</sup> One-year delay in conservation adoption, variable conservation to conventional yield ratios, an initial soil depth of 60 cm, a soil loss of 34.25 metric tons/hectare/year, and a corn price of \$2.75/ bu. were assumed. The new no-till corn planter is a six row planter, at a price of \$20,000, a seven-year expected life, and 10-percent interest rate for a 3.5-year mortgage.

TABLE 3. EROSION-DAMAGE FUNCTION (EDF) VALUES, WESTERN KENTUCKY, WALKER'S AND PROPOSED METHOD, VARYING YEARS DELAY IN ADOPTION<sup>a</sup>

Year delay	Conventional advantage	NPV of erosion induced productivity loss	EDF value Walker method	EDF value proposed method
1	\$7.00	\$6.38	\$0.62	\$0.62
2	7.01	6.57	0.44	0.97
3	7.02	6.75	0.27	0.95
4	7.03	6.94	0.09	0.74
5	7.04	7.10	-0.06	0.28
6	7.06	7.34	-0.28	-0.53
7	7.07	7.51	-0.45	-1.51

<sup>a</sup> An initial soil depth of 60 cm, a real discount rate of 4 percent, a soil loss of 34.25 metric tons/hectare/year, a corn price of \$2.75, and a value for  $y_B/y_A$  of 1.03 were assumed.

geous to delay adoption of no-till for one more year. No-till should be adopted from the start of the planning horizon when the cropland has 57.5 cm or less soil depth to the fragipan. For a soil depth of 60 cm and above, at least a five-year delay in the start of conservation practices is indicated.

The dynamics of capital investment were then introduced. The investment was assumed to be a 6-row no-till corn planter at a price of \$20,000, a seven-year expected life, and a 10-percent interest rate for a 42-month mortgage. All other assumptions remained the same. At a 4-percent real discount rate, the adoption of no-till at the start of the planning horizon is not suggested for cropland with a soil depth of 57.5 cm or above. With the given assumptions, no-till should be adopted for cropland with soil depth of 55 cm or below. If the no-till option involved the purchase of a no-till planter, then the adoption of no-till (conserva-

tion tillage) is delayed.

Table 1 presents a sensitivity analysis with respect to the output price. The higher the output price, the more desirable is no-till. An increase in the output price accompanied by a value of  $y_B/y_A$  of greater than one increases the present value of net-benefit differentials for the two sequences of activities (where soil depth decreases for the conventional practice) in favor of conservation. Table 1 implies that if corn price is high, farmers will more likely adopt no-till. Conversely, during times of persistently low corn prices, farmers (such as those in the geographic area with fragipan soils) will be less likely to adopt specific soil conservation practices.

The sensitivity analysis indicates that a high ratio of conservation to conventional yields accompanied by low discount rates and high corn prices could lead more farmers to adopt conservation practices such as no-till. When

variable production costs are \$92.39 per acre under conventional tillage, they can be covered only when the output level exceeds 33.60 bushels per acre. This yield is achievable at a soil depth of 36.8 cm. With variable costs of \$122.74 per acre under no-till, the break-even level is 40.71 cm. or 44.63 bushels of corn per acre (assuming conventional tillage to no-till yield ratio is one).

The sensitivity analysis also varied  $y_B/y_A$  ratios and interest rates. In Table 2, the discount rate and the  $y_B/y_A$  ratio are varied. At a specific interest rate, as little as a one percent shift in  $y_B/y_A$  could result in a substantial change in the calculated value for the erosion damage function. At a  $y_B/y_A$  of 1.03 or below and a discount rate of 4 percent, the adoption of no-till for decision period  $t$  is not suggested by the net present value rule. If  $y_B/y_A$  is increased to 1.035, conservation tillage should be adopted at a discount rate of 4 percent, but not at a discount rate of 6 percent. If  $y_B/y_A$  is 1.04 or above, the erosion-damage function values are negative, indicating that the switchover point from conventional to conservation tillage practices has passed and the conservation adoption is necessary. When the investment cost for a no-till corn planter was taken into account, no-till was adopted even at a 10-percent discount rate, assuming that in decision period  $t$  no-till had at least 5 percent greater yields than the conventional tillage.

Table 3 presents the values for the erosion-damage function using Walker's approach and the values calculated using the alternative function proposed in this study. The period when the adoption of no-till becomes profitable with Walker's framework is one year earlier than suggested by the analysis in this study. The postponement of conservation practices is a consequence of defining an erosion-damage function incorporating intertemporal cost information on conservation and conventional practices.

### CONCLUDING REMARKS

Results from the erosion-damage function assumed that the ratio of yields for no-till versus conventional tillage was greater than one [ $(y_B/y_A) > 1$ ]. At least for corn in Kentucky, production and cost data used in the evaluation reveal that high-yielding, soil-conserving production systems may be more costly in terms of variable and total operating costs than are conventional practices. The investment aspect of soil conservation may become irrelevant to

the farmer if production costs associated with the no-till system are similar to conventional tillage and a value for  $y_B/y_A$  of greater than one occurs. With more research on the technical aspects of no-till systems, the agronomic and economic competitiveness of conservation over conventional tillage practices may be enhanced over time.

In this study, a P-T function was estimated using average (index) data on changes in agricultural productivity at the national level. The approach is more appropriate if location-, crop-, and tillage-specific productivity data are used. Evaluation of the erosion-damage function was simplified by an assumption of constant production costs under no-till regardless of the soil depth. Such an assumption means the evaluation framework is applicable only for the cropland with fragipan horizon that experiences sheet and rill erosion, not on soils susceptible to gully erosion. The evaluation framework will be more realistic and its applicability will widen if a specific cost scenario and model are developed to relax this restrictive assumption.

Soil conservation decision factors, such as output prices, the yield ratio of conservation (no-till) to conventional tillage practices, and the discount rate, were each found to affect the decision. An increase in the output price (while  $y_B/y_A$  is greater than 1) will encourage corn farmers who operate on cropland with fragipan horizons to more quickly adopt conservation practices. Conversely, when output prices decrease, farmers will be less inclined to adopt soil conservation practices.

Just as increasing real output prices leads to the adoption of conservation practices, the yield ratio of conservation to conventional practices is also positively related to motivation of and efforts by farmers to adopt conservation practices. For a given level of production cost in period  $t_0$  (the beginning of a planning horizon), the higher the yield ratio, the more readily the farmer will adopt conservation practices. A higher yield ratio affects the conservation decision directly by increasing the immediate benefits from conservation tillage, and indirectly by giving more weight to the value of erosion-induced productivity loss over time.

The higher the discount rate, the slower the conservation adoption. In our analysis, real discount rates were used instead of nominal values. It is a matter of the decisionmaker's perception as to whether real or nominal discount rates should be used. If the cost of pur-



chasing a (new) no-till corn planter is considered, then the adoption of conservation tillage practice is postponed at least one more period. The decisionmaking procedure proposed in this study can be useful both for individual

farmers in making soil conservation decisions and for soil conservation agencies in determining soil conservation targets in a particular area.

## REFERENCES

- Ball, V. E. "Output, Input, and Productivity Measurement in U.S. Agriculture, 1948-1979." *Amer. J. Agr. Econ.*, 67(1985): 475-86.
- Burt, O. R. "Farm Level Economics of Soil Conservation in the Palouse Area of the Northwest." *Amer. J. Agr. Econ.*, 63(1981): 83-92.
- Crosson, P. R., and A. T. Stout. *Productivity Effects of Cropland Erosion in the United States*. Washington, D.C., Resources for the Future, 1982.
- Epplin, F. M., T. F. Tice, and L. K. Lee. "A Comparison of Economies of Size for Conventional and Conservation Tillage System." Paper presented at the AAEA Annual Meetings, Ithaca, New York. August 1984.
- Frye, W. W., and S. H. Phillips. "How to Grow Crops with Less Energy." In *Cutting Energy Costs, The 1980 Yearbook of Agriculture*, USDA, 1980.
- Griliches, Z. "The Sources of Measured Productivity Growth: U.S. Agriculture, 1940-60." *J. Pol. Econ.*, 71(1963): 331-46.
- Johnson, L. C. "Soil Loss Tolerance: Fact or Myth?" *J. Soil Water Conserv.*, 42(1987): 155-60.
- King, A. D. "Progress in No-till." *J. Soil Water Conserv.*, 38(1983): 160-61.
- Lingard, J., and A. J. Rayner. "Productivity Growth in Agriculture: A Measurement Framework." *J. Agr. Econ.*, 26(1975): 87-104.
- Maglaby, R., D. Gadsby, D. Colacicco, and J. Thigpen. "Trends in Conservation Tillage Use." *J. Soil Water Conserv.*, 40(1985): 274-76.
- Mueller, D. H., R. M. Klemme, and T. C. Dariel. "Short- and Long-Term Cost Comparisons of Soil Conventional and Conservation Tillage Systems in Corn Production." *J. Soil Water Conserv.*, 40(1985): 466-69.
- Pagoulatos, A., D.L. Debertin, and F. Sjarkowi. "Soil Erosion and Yield Uncertainty in Soil Conservation Decision." *Agricultural Economics Research Report 45*. Department of Agricultural Economics, University of Kentucky. May 1987.
- Phillips, R. E., R. L. Blevins, G. W. Thomas, W. W. Frye, and S. H. Phillips. "No-Tillage Agriculture." *Science*, 208(1980): 1108-13.
- Sharp, B. M. H., and D. W. Bromley. "Agricultural Pollution: The Economics of Coordination." *Amer. J. Agr. Econ.*, 61(1979): 591-600.
- Shurley, W. D., C. L. Moore, Sr., and R. L. Trimble. "1985 Kentucky Field Crop and Forage Budget Estimates." *Agr. Econ. Ext. No. 55*. University of Kentucky. April 1985.
- Solow, R. M. "Technical Change and the Aggregate Production Function." *Rev. Econ. Stat.*, 39(1957): 312-20.
- Taylor, D. "Evaluating the Long-Run Impacts of Soil Erosion and Net Farm Income in the Palouse Annual Cropping Region of the Pacific Northwest." Unpublished Ph.D. Thesis, Dept. of Agr. Economics, Washington State University. 1981.
- United States Department of Agriculture. *Conservation Tillage; Things to Consider*. Washington, D.C., 1985.
- Walker, D. J. "Erosion Damage Function to Evaluate Erosion Control Economics." *Amer. J. Agr. Econ.*, 64(1982): 690-98.
- Walker, D. J., and D. L. Young. "The Effect of Technical Progress on Erosion Damage and Economic Incentives for Soil Conservation." *Land Economics*, 62(1986): 83-93.
- Young, D. L., D. B. Taylor, and R. I. Papendick. "Separating Erosion and Technology Impacts on Winter Wheat Yields in the Palouse: A Statistical Approach." *Amer. Soc. Agr. Engineers*, Proceedings of a Conference on Erosion and Soil Productivity. 1985.