A SURVEY OF NONPOINT POLLUTION POLICY FORMATION; A PRELIMINARY ASSESSMENT OF THE ADOPTION OF MINIMUM TILLAGE CULTURAL PRACTICES

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Introduction

Agricultural land is one of the most important natural resources of the nation. However, this same resource, transported by wind and water, has been identified as one of the major sources of nonpoint source pollution.

This paper examines the relationship between the agricultural sector's contribution to soil erosion and the process of environmental degradation. The economic "solution" to the resulting externality problem is discussed and contrasted with existing nonpoint source pollution abatement policies which rely on individual investment in best management practices. Minimum tillage is identified as a best management practice which also appears to be a profitable investment decision for farmers. Minimum tillage is evaluated on its merits as an investment from the farmer's perspective and for its contribution to nonpoint source pollution abatement.

Soil Erosion and Environmental Quality

Soil erosion by water has resulted in sedimentation of our tributary streams at a rate of over 4 billion tons of sediment per year. Agricultural sources have been identified as a casual factor in approximately 50 percent of this sedimentation process [9, 25]. Resulting impacts include impairment of the environment necessary for healthy aquatic life, changes in water quality affecting home consumption and recreational uses, and increased maintenance of water transport systems [6, 15].

Soil erosion by wind is less severe, causing about 1 billion tons of soil erosion per year. Together wind and water caused erosion total about 5 billion tons of topsoil loss per year. On that basis, per acre soil loss in the United States is estimated to be 12 tons per acre per year, greatly exceeding the "tolerable" level (4 to 5 tons per acre per year) at which soil can replenish itself naturally [15].

Soil erosion also causes productive potential of cropland to be reduced. Although research has shown that crop production is diminished with the reduction of topsoil depth, the effect has been masked by the substitution of purchased production inputs such as hybrids, fertilizers, pesticides, mechanization, and management [8, 22].

Nonpoint Source Pollution as an Externality Problem

Agricultural economists have conceptualized the problem of soil erosion and environmental degradation as one of nonpoint source pollution which results in both production and consumption externalities. An externality is generally said to exist when the utility of one or more individuals is dependent upon, among other

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things, one or more activities which are under someone else's control. More formally, an externality is said to exist whenever

$$(1)\quad U_j = U_j(X_{1j},X_{2j},\ldots,X_{nj},X_{nk})\ j \neq k$$

where U_j is the utility of individual j, X_i (i = 1, 2, . . . , m, n) refer to activities and j and k refer to individuals. That is, an externality exists whenever the welfare of an individual j is affected by activities under his control (X_{ij}) but also by some activity (X_{nk}) which is under the control of individual or entity k [16].

The economics profession has developed a rich literature which considers the many facets of externality probelms. As it is beyond the scope of this paper to review this literature in any depth, the reader is referred to Buchanan and Stubblebine [5] or Baumol and Oates [4] for this purpose.

In an effort to synthesize much of this literature, Randall has identified three broad classes of economic solutions to externality problems: 1) market solutions resulting from the establishment of liability rules (ranging from full liability to zero liability) which serve as a starting point for negotiatons between pollutors and receptors, 2) systems of per unit taxes or subsidies (the Pigovian tax) and 3) systems of standards enforced by the threat of fines or imprisonment. The first class of solutions, the class most favored by economic theorists, relies on private negotiations, while the success of the second and third classes of solutions are dependent on some form of government intervention [16].

The market solution of private negotiations, although theoretically preferred, is not in practice a feasible solution to the externality problem caused by nonpoint source pollution. Clearly specified liability rules have not been developed in the area of soil erosion-related pollution. In addition, the potential of prohibitively high transactions costs argue against the feasibility of a market solution. High transactions costs in the case of nonpoint source pollution are a result of the size and diversity of the group of involved individuals. Also, the nonpoint source characteristic of the pollution problem makes exact identification of pollutors and receptors costly.

When a market solution to an externality problem is not feasible, the usual economic prescription is to develop a system of pollution taxes or effluent charges, the next most efficient system of pollution control [4]. But even so, it is recognized that economic wisdom is only one of many inputs in the total policy formulation process. Casual observation reveals that, in the case of erosion-related nonpoint pollution, a noticeable divergence exists between the recommendations of theoretical economists and the actual policy. The economists' suggestion of pollution control through a system of taxes or effluent charges differs considerably from the actual policy which emphasizes erosion control and pollution abatement through reliance on individual investment in best management practices.

The Policy Setting: Where Theory and Practice Diverge

Soil erosion, which serves as the primary medium of transfer for nonpoint source pollution, is not in itself a new concern to either farmers or agricultural economists. The disasterous soil loss effects of the Dust Bowl era served to develop a heightened consciousness and concern for the need to protect productive capacity through resource management, usually in the form of soil conservation practices. However, the recently recognized explicit linkage between soil erosion and changes in environmental quality has broadened the issue to include the more comprehensive effects of soil erosion on the next use of deleteriously affected resources, in particular water.

In 1972 the Federal Water Pollution Control Act, PL 92-500, was passed with the stated goals of making the nations streams and lakes swimmable and fishable by 1983 and eliminating both point and nonpoint sources of pollution discharge by 1985 [7]. Passage of the Clean Water Act, PL 95-217, in 1977 established a Rural Clean Water Program (RCWP) which specified the use of measures incorporating best management practices for the abatement of nonpoint source pollution. This legislation reflects the Environmental Protection Agency's belief that in many cases the goals of the act can be achieved by applying practicable best management practices. In cases where these conservation practices are inadequate, more vigorous controls will be added at a later date [20]. Primary responsibility for the program is assigned to state and regional agencies such as the Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS).

Sharp and Bromley [19] suggest that the reluctance to utilize a regulatory constraint as a policy device reflects a popular sentiment that legislative efforts to enhance environmental quality should proceed with minimum interference of individual farmer's activities, thereby reflecting the Jeffersonian doctrine of preserving the independence and virtue of small scale farming.

Musser [12] has offered an alternative, intuitively more appealing hypothesis explaining the divergence between theory and practice in the solution to the nonpoint source pollution externality problem. Based upon the political economy concept of disjointed incrementalism, Musser's hypothesis explains the emphasis on best management practices, rather than taxes or effluent charges, as a relative lack of information about effects of nonpoint source pollution. This paucity of information on social production functions and public objectives results in great uncertainty which is best managed by linking new policies and programs to past experiences. The direct linkage of environmental quality programs, such as the water quality program, with past program experience in soil conservation does appear to support this hypothesis.

Productive Capacity and Environmental Quality: An Investment Decision

Recognition of the policy link between soil conservation practices and environmental quality improvement has resulted in a re-examination of many traditional soil conservation issues. Recent emphasis has been placed on conceptualizing soil "not as a single resource but as a set of individual interrelated components which have both stock and flow dimensions" [17, p. 1093]. Defining soil conservation as a redistribution of resource use into the future relative to the present suggests a problem in capital theory, i.e., an intertemporal management of soil resources.

Viewing soil conservation as an intertemporal investment problem is conceptually helpful in analyzing the apparent difference between private rates of soil conservation (and hence environmental quality control) and socially desired rates. The indeterminancy of the appropriate discount rate, tenure arrangements, differences between societal planning horizons and the planning horizons of individuals, differences between individuals' time preferences and society's time preference, and public versus private risk preference are traditional concerns in investment decisions which appear to be applicable to soil conservation and related environmental quality investment decisions [11, 17]. The policy level rejection of the theoretically appropriate externality framework in favor of a system relying on individual incentives for investment in best management practices has therefore, reformulated the problem of nonpoint source pollution abatement in terms of an individual farmer's investment decision. Voluntary adoption of best management practices will depend in part on the value individual farmers place on soil and nutrient losses which decrease productive capacity. Financial incentives for investment therefore, assume what Sharp and Bromley [19, p. 593] call a "pivotal role" in inducing the adoption of pollution abatement technology on an individual basis.

Attitudinal surveys exploring the gap between private economic incentives for soil conservation and social objectives for pollution abatement have found that farmers perceive private economic incentives to be the primary motives for investment in soil conservation practices. However, from the farmer's perspective, economic incentives for most forms of conventional soil conservation best management practices (e.g., crop rotations, cover cropping, terracing and contouring) are too weak to induce investment [18].

One possible exception to this investment picture is the increasing adoption of minimum tillage cultural practices. Minimun tillage refers to a reduction in soil disturbances from that of the conventional methods. Research findings indicate that some minimum tillage systems can virtually eliminate soil erosion due to more stable soils and higher infiltration rates [9, 14]. The acreage cultivated using minimum tillage cultural practices in the United States increased from 3.8 million acres in 1963 to approximately 33 million acres in 1974 [23].

Recognized as a best management practice due to its soil conserving characteristics, minimum tillage is also increasingly known on the merit of its ability to increase productive capacity while reducing labor requirements [8, 14]. Adoption of minimum tillage practices does, however, involve a private investment decision for the farmer who must purchase a different complement of equipment.

Private Investment Incentives: The Farmer's Perspective

Several minimum tillage systems exist. An extreme case of minimum tillage is a practice that requires no seedbed preparation before planting and no mechanical tillage after planting. This practice is referred to as "no-till." This section discussed technical and economic factors in the adoption of a no-till system for corn and soybean production in the Ohio Valley region.

Several technical aspects indicate that no-till practices potentially provide economic incentives for its adoption. One advantage is that plowing and disking operations are virtually eliminated, thus reducing the amount of labor and machinery operating time associated with a crop. Another important consideration is the potential difference in yields between the conventional and no-till methods. Evidence for higher yields is provided by Harrold, et al. [8] in their study of corn yields and associated erosion and run-off. Their findings indicate that, on averge, no-till corn out yields conventional corn — 116.2 bu/acre to 103.8 bu/acre. Perhaps one explanation for the higher yields resulting from the no-till method is the soil moisture conserved. Triplett, et al. [21] found that greater yields of corn are associated with increased water infiltration and soil moisture.

The technical aspects of no-till indicate economic benefits. But other factors such as increased chemical and fertilizer costs and the costs of the no-till equipment must be considered.

Method of Analysis. The economic feasibility of converting from conventional to no-till methods can be examined by partial budgeting and net present value analyses. A partial budget is a budget of the differences between two situations. The objective of partial budgeting in evaluating the economic feasibility of converting from conventional to no-till methods is to find the annual net return (quasi-rent) to the tillage equipment necessary for the change. The returns over the lifetime of the equipment can be estimated by a series of partial budgets which reflect each annual situation.

Appropriate evaluation of a capital investment must consider the time-value aspect of the stream of net returns to the investment. The standard capital theory approach for evaluating capital investment is to value all benefits and costs at the same point in time. Usually this is accomplished by valuing at the present by discounting the future net returns by some required rate of return on the investment, i.e., the required interest rate necessary for making the investment. Valuing all costs and benefits at the present is generally referred to as net percent value (NPV). An NPV greater than zero indicates that making the capital investment will add to the value of the firm or individual [10]. The general mathematical form of an NPV model is:

$$(2) \quad NPV = -C_o + \sum_{t=1}^{N} \frac{Q_t}{(l+r)t} + \frac{C_N}{(l+r)}N$$

where:

NPV = the net present value

C_t = the market value of the asset at time t

Q_t = the return or quasi-rent to the investment at time t

t = the discrete time measured from the time the investment is made, i.e., t= 0, 1, . . . , N, where N is the number of periods of ownership

r = the required rate of return necessary for making the investment.

The objective in using an NPV analysis in deciding to convert from conventional to no-till farming is to evaluate if the present value of the returns to the no-till equipment (found in partial budgeting) exceeds the present value of the net investment cost (the initial cost reduced by the present value of the market value of the equipment at the end of the ownership period).

Although benefits from higher productivity may be reaped by the farmer from adoption of no-till practices (i.e., soil and water conservation also may be viewed as an investment), the analysis presented is conservative in that productivity is assumed to remain constant for both the conventional and no-till methods. Also, the no-till method is assumed to have no yield advantage over the conventional method.

Soybean Analysis. For the feasibility of no-till soybeans, a comparison between conventionally tilled soybeans and a no-till soybean-wheat double cropping system is examined for a 400 acre farm. The double cropping system is possible with no-till practices because of the reduction in the time required for soybean seedbed preparation. A no-till planter ($8,500) and a grain drill ($4,400) are the additional investments necessary for this double cropping system. It is assumed that all conventional tillage equipment is kept.

Partial budgets of annual net returns to the additional equipment were constructed for a ten-year period for various product price situations. The estimated cash costs were 1981 estimates for Kentucky [1] and were assumed to remain constant over the ten years except for repair, tax, and insurance costs. Costs for the extra combine repairs (combine initial cost: $28,200) and repairs for the no-till planter and grain drill were calculated from formulas given in the Agricultural Engineers Yearbook [2, p. 254]. The property tax and insurance costs were assumed to be .6 and 1.5 percent of the remaining values (market values), respectively. The remaining values were calculated by the formulas given in the Agricultural Engineers Yearbook [2, p. 253]. The results of the partial budgets for the various price situations are given in Table 1.

Table 1. Results of Partial Budgets for Various Soybean and Wheat Prices for 400 Acres

	Net Returns (Q_t) to Additional Equipment[a]		
Years	$3.25/bu Wheat $6.50/bu Soybeans	$3.50/bu Wheat $6.75/bu Soybeans	$4.00/bu Wheat $7.00/bu Soybeans
1	2,523.02	5,523.02	12,523.02
2	2,171.10	5,171.10	12,171.10
3	1,840.92	4,840.92	11,840.92
4	1,379.61	4,379.61	11,379.61
5	938.00	3,938.00	10,938.00
6	406.74	3,406.74	10,406.74
7	(125.23)	2,874.77	9,874.77
8	(684.17)	2,315.83	9,315.83
9	(1,296.84)	1,703.16	8,703.16
10	(1,875.07)	1,124.93	8,124.93

[a]Space precludes the many details involved in the partial budgeting analysis. The authors will furnish details upon written request.

Net present value analyses were preformed for the various price situations under various marginal income tax and required rate of return scenarios. The results are given in Table 2. At wheat prices of $3.25/bu. and soybean prices of $6.50/bu., not enough positive net return is generated to justify the investment for any of the tax rates or required rates of return examined. However, at prices slightly higher, $3.50/bu. for wheat and $6.75/bu. for soybeans, the investment becomes attractive for all the tax rates and required rates of return examined. At prices which reflect the more current situation, $4.00/bu. for wheat and $7.00/bu. for soybeans, the investment becomes very attractive, yielding a very high net present value.

Corn Analysis. For corn, a comparison between conventionally tilled corn and no-till corn was made. A no-till planter ($8,500) was the only investment necessary for the conversion from conventional to no-till. All conventional equipment was assumed to be retained.

Partial budgets of annual net returns to the additional equipment were constructed for a ten-year period. The cash costs and the product price were based on 1981 Kentucky estimates [1]. These costs and prices were assumed to remain

Table 2. Results of Investment Analysis of Equipment Needed in Converting from Conventional Soybeans to No-Till Soybean — Wheat Double Cropping.

Price of Wheat ($/bu)	Price of Soybeans ($/bu)	Marginal Tax Rate (%)	Required Rate of Return (%)	Net Present Value ($)
3.25	6.50	25	3	- 3,464
3.25	6.50	35	3	- 3,081
3.25	6.50	25	9	- 4,676
3.25	6.50	35	9	- 4,483
3.50	6.75	25	3	15,727
3.50	6.75	35	3	13,553
3.50	6.75	25	9	9,726
3.50	6.75	35	9	8,030
4.00	7.00	25	3	60,511
4.00	7.00	35	3	52,364
4.00	7.00	35	9	43,455
4.00	7.00	25	9	37,231

constant over the ten years, except that the repair, tax, and insurance costs were calculated in the same manner as in the soybean analysis.

The partial budgets reflect that, on a per acre basis, converting from conventional to no-till corn is not profitable (when labor costs are not included) because of the higher level of chemical and fertilizer usage. However, no-till corn requires less labor (approximately 2 hours per acre) than conventionally tilled corn. Given that operations can be expanded due to this labor savings, no-till methods potentially become economically feasible.

In analyzing the feasibility of converting from conventional to no-till corn, expanded no-till operations were compared to the base 400 acre conventional operation. Additions of 25 acres and 166 acres for the no-till operation were considered. The 25 acre amount is a relatively small amount that could possibly be available for expansion from currently existing marginal lands that are not being cultivated. The 166 acres represents the extra amount of land that could be planted if all labor savings from no-till methods could be utilized. The results of partial budgets of these two expansions are given in Table 3. Investment feasibility of the additional equipment was analyzed using NPV methods for the two land expansion amounts under various marginal income tax and required rate of return scenarios. The results are presented in Table 4.

The results indicate that even small amounts of expansion make no-till equipment an attractive investment. Even when cash rent of $80 per acre is included, the expansion of only 25 acres is still large enough to yield an attractive NPV amount for all tax rates and required rates of return examined. When the labor savings from no-till can be fully utilized in expanded operations, the net present value is extremely high, being thousands of times greater than the initial investment. It should be noted that the price of corn used in the analysis was $3.00 per bu. It is apparent that prices somewhat lower would still yield positive net present value amounts.

Table 3. Results of Partial Budgets for Various Expansion Amounts of Corn

Years	Net Return (Q_t) to Additional Equipment[a] 25 - acre Expansion	166 - acre Expansion
	---DOLLARS---	
1	4,490.21	43,021.44
2	4,447.32	43,777.02
3	4,397.31	42,533.28
4	4,342.79	42,215.84
5	4,284.76	41,914.58
6	4,223.84	41,603.36
7	4,160.48	41,283.80
8	4,095.47	40.956.99
9	3,999.07	40,595.28
10	3,958.52	40,285.00

[a] Space precludes the many details involved in the partial budgeting analyses. The authors will furnish details upon written request.

Table 4. Results of Investment Analysis of Equipment Needed in Converting from Conventional Corn to No-Till Corn

Amount of Land Expansion	Marginal Tax Rate	Required Rate of Return	Net Present Value
(acres)	(%)	(%)	($)
25	25	3	22,206
25	35	3	19,194
25	25	9	14,767
25	35	9	12,514
25*	25	3	9,411
25*	35	3	8,105
25*	25	9	5,140
25*	35	9	4,171
166	25	3	262,367
166	35	3	227,333
166	25	9	195,994
166	35	9	169,578

* Includes rental costs of $80 per acre.

Other Considerations. Given the foregoing analyses, it appears that many farmers should have adopted the no-till technique by now. Indeed, the adoption of minimum tillage practices in the U.S. has increased dramatically in recent years.

However, other factors warrant consideration. A considerably higher level of technical management is necessary with no-till than with conventional-till. The need for higher management skills comes about due to the need for more timely applications of herbicides and insecticides in controlling pest problems. Thus, in the adoption of no-till practices, the uncertainties associated with a more complex managerial situation must be considered. Nevertheless, as more experience is gained, more information becomes available to farmers and pesticides more suitable for minimum tillage agriculture are developed, much of the current uncertainties will disappear. Given the strong economic incentives currently available, it appears that the adoption of minimum tillage systems will occur at a rapid rate in the near future.

Summary and Conclusions

The policy decisions to address the problem of agricultural non-point source pollution abatement by relying on private adoption of best management practices, rather than some form of regulation, has resulted in increased reliance on investment decisions made by farmers. This paper discusses one of the more promising best management practices — minimum tillage — from the perspective of society and the farmer.

Investment analyses were performed for converting from conventional to no-till methods for the two most important crops in the Ohio Valley region — crop and soybeans. The analyses yielded results which indicated very strong economic incentives for adopting no-till methods. It is important to note, however, that such a tillage system requires more sophisticated managerial skills, meaning more uncertainty for potential adopters. Given more information from research and experience, the high degree of uncertainty should diminish, and the adoption rate of minimum tillage should increase. It should also be noted that this analysis was based on two crops for which the no-till system has been the most successful and on the assumption of high management skills. In regions in which other crops are important, much research is needed for the technological advances necessary for economic feasibility.

From society's perspective, minimum tillage systems are a vast improvement over conventional methods in terms of soil erosion and its concomitant water pollution. Increased applications of chemical inputs associated with minimum tillage systems however, may contribute to nonpoint water pollution through percolation to ground water. Although minimum tillage may not provide the level of abatement optimally preferred by society, potentially high costs of regulation will be avoided.

In conclusion, private investment in minimum tillage systems has the potential for satisfying farmers' profit motives, while at the same time providing society with acceptable measures for nonpoint source pollution abatement.

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