A Whole-Farm Economic Analysis of No-tillage and Tilled Cropping Systems

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ABSTRACT

Cotton, corn, grain sorghum, soy, and wheat-soy doublecrop productivity were measured on an upland site with chisel tillage (CT) and no-tillage (NT) during a 10 year crop management study. An integer programming model was developed to allocate resources among different crop enterprises with different tillage systems on a whole farm basis with the objective of maximizing profits. This model was used to study optimal resource use as farm size increased. Labor for machine operation was treated as a finite resource and Conservation Reserve (CRP) at $35 acre-1 was included as a default option. Results were sensitive to commodity prices and crop productivity. In the whole farm analysis, NT was the dominant choice; cotton was the most profitable crop and displaced CRP at 400A with $.58 lint prices. Economies of scale were evident as profits increased with subsequent 100A increments as fixed machinery and labor costs did not increase. Worker productivity became limiting for NT cotton above 500A and at 800A the model switched to corn handled by one worker. In the CT system, cropping was not initiated below 500A with corn and grain sorghum as the crop choices. Worker productivity in NT systems in terms of acreage managed was approximately double that for CT. As acreage increased, other crop enterprises were added. Net returns for NT cropping were greater than for CT at equivalent land areas. Whole farm analysis offers a means of crop enterprise comparison that can assess benefits of conservation tillage in terms of both worker productivity and profitability.

KEYWORDS

Conventional tillage, no-tillage, integer programming, commodity pricing

INTRODUCTION

Economics drives the adoption or rejection of new agricultural practices. Crosson *et al.* (1986) addressed farmer adoption of conservation tillage practices and stated, "In the future, as in the past, farmers' decisions to adopt reduced tillage will be made primarily on their calculations of its economic worth". Crosson *et al.* (1986) noted that field operations are eliminated as conservation or no-tillage is adopted, leading to reduced labor for field operations and less equipment for pre-plant land preparation. Reduced investment in equipment results from eliminated operations and using smaller, less expensive tools and power equipment. This in turn reduces fixed costs for equipment and interest on investment. Pesticide amounts, especially herbicides, are increased as tillage operations are eliminated and these increased costs offset some of the savings in equipment and labor. Crosson *et al.* (1986) states, "The value to the farmer of the time saved depends on the value he or she places on alternative uses of time, such as other farm work, off-farm employment, or increased leisure. Clearly the value will be different for different farmers but for most, if not all, it will be positive."

The potential for expanding operations or adding enterprises with the same labor and equipment has rarely been considered in published analyses. The main reason for this neglect is methodological. The method of partial budgeting is most frequently used to evaluate the profitability of technology innovations, including alternative tillage systems. Partial budgeting is essentially a comparison of the net change in costs and returns between alternative systems, with the key assumption that all other costs and returns are unchanged. The approach also assumes that hourly labor to perform field operations is neither limiting nor slack. This assumption is unrealistic since many farms hire full-time seasonal or annual labor. While differences in fixed equipment costs can be evaluated using partial budgeting, the comparisons are often not robust because they are made, often implicitly, on the basis of a single farm scale. Equipment is assumed to be used efficiently, regardless of

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farm size. In actuality, partial budget comparisons should vary across farms with different acreage and fixed equipment and labor resources.

Innovations in tillage systems require modeling in a representative, whole farm framework where land, labor and capital are considered finite resources and successful operators are those who use these most efficiently. To address both economic and management questions, crop production research was initiated in the deep loess area of northern Mississippi in 1987 by the USDA ARS National Sedimentation Laboratory cooperatively with The Mississippi Agricultural and Forestry Experiment Station. Objectives included development and evaluation of systems that would reduce off-site sediment movement and preserve long-term productivity by minimizing soil loss, while offering growers a profit potential.

MATERIALS AND METHODS

An upland site occupied by grassland was selected and prepared by applying lime and fertilizer to satisfy needs indicated by soil tests, tilling the experimental blocks (10), and planting wheat for winter cover with the first crops in 1988. Soils on the site were dominantly Grenada silt loam (Fine-silty, mixed, active, thermic Oxyaquic Fraglossudalfs), but included small amounts of associated Memphis (fine-silty mixed, thermic Typic Hapludalf) and Loring (fine-silty, mixed, thermic Typic Fragiudalf) silt loams. Memphis soil has no restrictive horizon, while Grenada and Loring soils contain a restrictive pan at the 18 to 22 in. depth. Depth to pan is commonly less because of erosion during prior use. Crops included cotton, grain sorghum, soybean, and wheat in a doublecrop system with soybean. Corn was included in a separate experiment begun in 1989. Tillage systems included CT (chisel plow, disk 2x, smooth, plant, cultivate postemergence 2x), NT (spray, plant, harvest), and two reduced tillage systems. Initially, all crops except wheat and doublecrop soybean were planted in 36 inch rows. After 1992, all soybean was drilled in 10 inch rows. NT cotton included a wheat cover crop which increased the surface residue, soil protection, and cost of production (~$20 per acre). In the first phase of the study (through 1992), NT management proved suitable for all crops. In 1993, corn replaced grain sorghum and reduced tillage systems were changed to NT. One of the NT cotton systems utilized winter weed growth for cover rather than a planted cover crop. By the third year, crop yields reached 95 percent parity with the long term NT system with wheat cover. Because of favorable productivity and reduced cost, this system was used in the analysis described below. Earlier publications from these management studies included cotton production (Triplett *et al*., 1996). Monthly precipitation records as well as greater details on cultural practices are available in earlier publications (Dabney *et al*., 1993, Triplett *et al*., 1996).

In the whole farm analysis, the calendar was divided into 13 4-wk periods with assignment of optimum planting and harvest timing for crops. Days suitable for field operations in each period (Spurlock *et al*., 1995) were coupled with equipment performance rates to calculate potential crop acreage per worker. The Revised Universal Soil Loss Equation was used to calculate soil loss potential for different crops and tillage practices. These were applied to systems to determine compliance with soil loss restrictions and eligibility for Farm Program payments. Since this is an upland site with significant erosion potential, soil was left undisturbed following harvest and all tillage operations were performed within one month of planting. Number of years for each system, mean crop yields, and operations performed for different crop management systems during the life of the study are shown in Table 1. Crop yields and historic commodity prices were used to calculate gross returns for crop and tillage combinations. Initial labor was supplied by the operator with returns to land, labor, and management representing operator earnings. When all available operator time was committed and economic conditions were favorable, additional labor for machine operation was hired for an entire year at $20,000 per worker. Costs of inputs and fixed costs for equipment necessary for crop production were entered into the General Algebraic Model System and the selection of crops, equipment inventory, and labor hired that maximized profits was solved for specified acreages. Entering the land into the Conservation Reserve Program at $35 per acre was included as the default option.

RESULTS

Crops selected, input costs, labor hired, machinery costs, and returns for various acreages in the whole farm analysis are shown in table 2. Commodity prices are average for the last 5 years of the study. The model selected the CRP option until available area for cropping reached 400A. Before this point, the purchase of one tractor and rotary cutter to maintain the CRP acreage was designated. No-tillage cotton was selected initially as the most profitable crop and was first produced at 400A. Profits increased markedly ($23K to $43K) when acreage increased to 500A, because the fixed machinery cost ($58K) remained constant. The fixed cost of cotton harvest equipment is a major component of the cotton machinery budget. At 515A, time became limiting during harvest season for one worker, and CRP was selected to complete the 600A increment. At 800A, the program shifted to NT corn with one worker, time demands decreased, profit per acre increased, and the equipment budget was less than for the smaller acreage of cotton. At 900 and 1000A, time became limiting for corn planting and a NT corn-soybean rotation was chosen with

Table 1. Cropping system, average tillage operations performed, and yield. Insecticide applications and harvest operations not shown. Yields are express as lbs lint acre^{-1} for cotton, cwt acre^{-1} for grain sorghum, and bu acre^{-1} for corn and soybean. The numbers in parenthesis are years of data collected for yield in each system.

Crop	Tillage, crop culture	Yield
Cotton, cv	Chisel, 2spread, 1.7disk, bed, do-all, plant, 2spray, 3cult, shred	612 (9)
Cotton, ridge	2Spread, NTplant, 2 spray, 3 cult, shred	598 (4)
Cotton, min	2 Spread, mulch finisher, NT plant, 2 spray, 2 cult, shred	658 (4)
Cotton, NT,wh	2Spread, NTplant, 3 spray, shred, drill cover	716 (9)
Cotton, NT	2Spread, NTplant, 3 spray, shred	616 (5)
GS, cv	Chisel, 2spread, disk, plant, spray, 2cult	39.6 (5)
GS, ridge	2 Spread, Ntplant, spray, 3 cult	34.5 (5)
GS, min	2 Spread, mulch finisher, Ntplant, spray, 2 cult	36.1 (5)
GS, NT, vetch	2 Spread, Ntplant, 2spray, drill cover	42.4 (5)
GS, NT, wh.sb	2 Spread, Ntplant, 2spray, drill wheat	43.2 (5)
Cn, cv	Chisel, disk, 2spread, plant, 2spray, 2 cult	128 (5)
Cn,NT,ve	2 Spread, 2 Spray, Ntplant, drill vetch	111 (5)
Cn,NT,wf	2 Spread, NT plant, 2.6 spray	120 (5)
Cn,NT,wh,sb	2 Spread, NT plant, 2.6 spray, drill cover	131 (5)
Cn,NT,wh,ct	2 Spread, NT plant, 2.6 spray, drill cover	128 (5)
Sb.cv	Chisel, 1.4 disk, spread, plant, 1.5 cult, 2 spray	25.5 (10)
Sb.rt	Spread, plant, 3.2 cult, 1 spray	26.9 (5)
Sb.mt	Spread, mulch finisher, plant, 3 cult, 1.4 spray	25.7 (5)
Sb.NT.wf.sb	Spread, drill, 4.4 spray	31.4 (5)
Sb.NT.wh.sb	Spread, drill, 3.1spray, drill	24.3 (10)
Sb.NT cn.wh.	Spread, drill, 3.1 spray	22.7 (5)
Sb.NT.gs wh.	Spread, drill, 3.1 spray	28.1 (5)

NT doublecrop wheat-soybean occupying the additional acreage. Although less profitable than corn, doublecrop wheat-soy occupied underutilized time periods and was produced with the same equipment used for the corn-soy sequence. Labor demands are high for all crops during planting and harvest seasons. While crop enterprises with different planting and harvest seasons may utilize labor most effectively, these may not be cost effective at smaller acreages because of increased equipment investment. As acreage is increased, other crop enterprises are added and labor is used more effectively. At 5000A, the cropping mix was approximately half cotton with corn and soy comprising the other half.

Although the model did not choose tilled systems at any acreage amounts, NT was disabled in the program, and solutions for tilled management were made for a series of acreages (Table 3). In the CT solutions, cotton did not appear at any time, reflecting lower CT cotton yields in the production study (Table 1). Crop production was not initiated until the 500A level. Corn and grain sorghum were chosen as crops and were managed by a single machine operator with a net of $26 per acre. Of interest, corn was limited to 451A because of time constraints for land preparation and planting, and grain sorghum occupied the remaining area. Both crops utilized the same planting and

Table 2. Solutions that maximize profits at various acreages. Costs and returns in \$ x 1000s. Per acre returns in \$. Assumed commodity prices are \$ 0.58 per pound of cotton, \$ 2.38 per bushel of corn and \$ 5.95 per bushel of soybean.

Total Acres	300	400	500	600	700	800	900	1000	2000	5000
CRP	300			85	185					156
Cotton		400	500	515	515				1500	2118
Corn						800	420	420	500	1363
Soybean							420	420		1363
Doublecrop							61	161		
Gross $(K)	2	185	232	240	240	213	229	254	830	1678
Profit $(K)	4	23	43	49	52	62	80	92	201	554
AMTA	8	11	14	17	20	23	25	26	56	141
Var. Input		102	128	131	132	125	119	133	461	903
Var. Mach	--	14	17	18	18	11	13	16	59	111
Fix Mach	6	58	58	58	58	38	41	41	126	172
Total Mach	6	72	76	76	76	49	54	57	184	282
Payroll	0	0	0	0	0	0	0	0	40	80
\$ acre^{-1} net	13.5	57	86	82	75	78	89	92	100	111
T.mach hrs		670	838	864	864	450	484	570	2790	4958
Mach \$ acre-^{1}	20	180	152	127	109	61	60	57	92	56

harvest equipment but at different time periods. In the NT solution (Table 2), one machine operator had time to manage 800A corn. At 700A and 800A, soy replaced grain sorghum and corn remained at 445A. Shifting production to soy required the purchase of a drill, reflected in the fixed machinery cost. At 1000A, the most profitable solution involved all corn but required the employment of two additional workers. At 5000A, corn occupied 4966A, sorghum 34A, and 10 machine operators were employed.

DISCUSSION

With lower cotton prices, corn and/or soy may be the first crop selected (data not shown). The program selected NT production in almost all cases. Contributing factors included increased cotton yield with NT, favorable yields for corn and soys with NT, compliance with farm program restrictions on erosion, and greater worker productivity because of fewer operations during planting season. In some analyses with CT yields high enough to favor this system initially, the program would switch to NT as acreage increased and time became limiting, rather than hire an additional machine operator. NT corn requires approximately 0.56 hr per acre of machine time, while NT cotton requires 1.68 hr per acre during crop production, respectively. Tilled corn production required 1.1 hr per acre, essentially double the time for NT production. Since time requirements for harvest are similar in both systems, the increase is entirely during the planting season when time available for field work is also limiting for NT, which has fewer operations. Per acre net returns for tilled systems were half those of NT. Contributing factors included no AMTA payments, greater machine costs for production of like crops, and greater labor requirements for tilled systems. While AMTA payments contribute measurably to net income, they represent less than half the difference at smaller acreages.

The integer programming approach allows for a comparison of crop enterprises that evaluates conservation tillage in terms of both worker productivity and profitability. The analysis is sensitive to farm size, commodity prices, and labor availability. Farm gross income represents a product of commodity prices and crop yield, neither of

Table 3. Solutions that maximize profits for tilled systems at various acreages. Costs and returns are in $ x 1000 and per acre returns in $. Assumed commodity prices are $ 0.58 per pound of cotton, $ 2.38 per bushel of corn, $ 5.95 per bushel of soybean, and $ 3.91 per cwt grain sorghum.

Total Acres	400	500	600	700	800	900	1000	2000	3000	5000
CRP	400				2	900				
Cotton										
Corn		451	451	445	445		1000	1440	3000	4966
Soybean				255	353			660		
GrainSorg		49	149							34
Gross $(K)		132	148	159	170	6	277	464	831	1381
Profit $(K)		13	17	21	24	22	31	102	178	321
AMTA	11	0	0	0	0	25	0	0	0	0
Var. Input		65	74	76	82	0	135	222	406	675
Var. Mach		10	12	15	17	0	20	42	62	104
Fix Mach	6	44	44	47	47	8	50	57	65	82
Total Mach		54	56	62	64	8	70	99	127	186
Payroll $	0	0	0	0	0	0	40	40	120	200
$ acre^{-1} net	19	26	29	29	30	25	31	52	59	64
T.mach hrs		558	667	764	866	0	1118	2188	3356	5593
Mach $ acre-^{1}	15	108	93	90	80	9	70	50	42	37

which are under complete control by producers. Rather, gains in profitability derive mostly from improved management of production costs. Results from this analysis clearly demonstrate that NT systems more effectively utilize resources of land, labor, and capital. Because of different harvest machine requirements, producers are unlikely to change from cotton production to corn or soy based on minor shifts in commodity prices. However, the relative mix of crops (corn, soy, doublecrop soy following wheat), which employ similar equipment for production, could be adjusted based on commodity price, projected yield, land available for production, and labor supply.

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