Stochastically Efficient Tillage Systems and Production Strategies: Implications for Conservation Compliance

Francis M. Epplin
David E. Beck

Francis M. Epplin is a Professor and David E. Beck is a former Research Assistant, Department of Agricultural Economics, Oklahoma State University. This is professional paper PP-3014 of the Oklahoma Agricultural Experiment Station selected for presentation at the American Agricultural Economics Association annual meeting, July 30-August 2, 1989, Baton Rouge, Louisiana.

#6636

Stochastically Efficient Tillage Systems and Production Strategies: Implications for Conservation Compliance

Abstract

Conservation compliance requirements will influence wheat production systems in the Southern Plains. Estimates of net returns were computed for 18 systems. One of the conventional tillage strategies dominates by first degree stochastic dominance. A bounding procedure was used to compare alternative cumulative distribution functions.

Stochastically Efficient Tillage Systems and Production Strategies: Implications for Conservation Compliance

Millions of acres which are typically seeded to hard red winter wheat in the Southern Plains exceed the highly erodible classification. Use of current production systems will jeopardize conservation compliance requirements for many producers. Alternative production systems to produce winter wheat will be required to limit soil movement to legislated levels.

Cheat and other winter grasses, including downy brome and wild oats, often become major weed problems in monoculture winter wheat fields. The primary method of controlling cheat has been to use a tillage system which includes the moldboard plow. The moldboard buries cheat seeds to a depth from which they can not emerge. However, a moldboard will cover 95 to 100% of the surface residue. In the absence of other soil conserving practices such as terracing, strip cropping, or contouring, it will be impossible to use a moldboard plow on land in the highly erodible classification and comply with conservation requirements for participation in commodity programs.

Much of the winter wheat which is produced in the Southern Plains is seeded early to produce forage in the fall which can be grazed by livestock during the winter. If livestock are removed prior to the jointing stage (typically early March), the wheat will produce a grain crop. Wheat may be seeded as early as August and as late as November. However, if the crop is seeded early, and if a moldboard plow is not used, serious infestations of cheat and other winter grasses result. Wheat yields are reduced and weed seeds contaminate harvested grain.

If seeding is delayed until late in the fall, after most of the weed seeds near the surface have germinated, cheat could be controlled with conservation tillage systems which do not include use of a moldboard. However, if seeding is delayed, the wheat crop will not produce sufficient forage for winter grazing and potential earnings from supplementary livestock production are foregone.

Zero tillage grain drills, which plant seeds directly into the stubble of the previous wheat crop, are available from manufacturers. Herbicides, including a herbicide for control of cheat, which are essential components of zero tillage production systems, have been registered for use for continuous winter wheat production. However, the economic impacts of production systems which depend upon herbicides to control cheat have not been determined.

Objective

The objective of the research reported in this paper is to determine if production systems which rely upon herbicides recently registered for use on winter wheat in the Southern Plains are economically competitive with a conventional tillage system. Estimates of expected returns and costs are generated for three tillage systems and four alternative planting months. Estimates are computed to reflect revenue from grain production, and to include revenue from both the production of wheat grain and live weight gain of grazing livestock for August and September planting strategies. The overall objective is to determine which of the 18 alternative production systems are stochastically efficient.

Procedure

A representative farm approach was used to estimate production costs. Farm size was fixed at 1,240 tillable acres. All tillable land was assumed to be seeded to continuous winter wheat. Weather information was used to estimate the number of field work days available during critical weeks. Machinery complements were defined for a conventional tillage "farm", a one tillage "farm", and a zero tillage "farm" that would enable the required field operations to be completed in the available field work days in 80% of the years. In other years field work would extend into following weeks, or work days would have to be extended beyond the assumed level of 10 machine hours per tractor per day.

An enterprise budget generator was used to prepare consistent estimates of operating costs and machinery ownership costs for each of the three tillage systems for each of four planting months (Kletke). A representative enterprise budget was also used to estimate the returns and costs for the livestock activity. Estimates of net returns to land, management, overhead, and risk were generated for each of the production strategies for each year for which data were available. A stochastic dominance software package was used to evaluate stochastic efficiency (Cochran and Raskin).

Data

Wheat grain yields for both conventional and zero tillage systems were obtained from a study conducted over four growing seasons at an experiment station in the Southern Plains. Planting dates were varied from the middle of August to the middle of November at approximately 30-day intervals. Zero tillage consisted of planting directly into the residue of the previous season's winter wheat crop. Yield data were not available for the budgeted one tillage system. The means of the average conventional and average zero tillage system yields for each planting month were used to represent the yield for the one tillage system.

Grain yield data were available for the four years of the agronomic study. However, forage yield data were not available. Forage value was estimated by budgeting returns and costs of a stocker steer with an initial weight of 450 pounds, placed on wheat in November and removed from the wheat in March at 665 pounds (Walker et al. 1987). For the purposes of this analysis, it was assumed that all wheat planted in the months of August and September could support a stocking density of 0.4 animals per acre. This is a typical stocking density in the region (Walker et al. 1988). Since fall growth is essential to produce sufficient forage for winter grazing, the livestock activity was not included for wheat planted in October and November.

Prices were obtained from various USDA publications. Estimates of returns for each of the four years for each of the 18 production systems were generated. Production costs, wheat grain yields, and grain prices were treated as stochastic variables.

Stocker weight gain was assumed to be the same across all wheat production systems and years. Variability in stocker income resulted from variability in prices. Returns from the stocker enterprise were held constant across all tillage systems, however, they varied over the years. Estimated returns to land, management, overhead, and risk from the stocker activity over the four years were $41.96, $20.98, $26.08, and $1.73 per acre. Hence, the expected return was approximately $23 per acre, or $28,000 per year for the 1,240 acre farm. The farm would support 496 stocker steers which, depending upon the price of steers, could require over $150,000 of operating capital in a typical year. For the analysis it was assumed that an unlimited amount of capital was available at market interest rates.

Results

Three sample budgets are included in table 1. The budgets include examples of income from an acre of wheat grain as well as income generated by 0.4 of a stocker steer. Costs are included for the wheat grain and stocker production activities.

The budgets reflect the expected returns and expected costs for each of the three tillage systems with average yields from September plantings and one set of prices. The budgets indicate the relative importance of herbicides for both alternative systems.

Table 1. Summary of wheat grain and supplementary winter grazing enterprise budgets for three alternative tillage systems with September planting dates (per acre)

			Conventional Tillage		One Tillage		Zero Tillage	
	Unit	Price or Cost per Unit (dol.)	Quan. per Acre	Value per Acre (dol.)	Quan. per Acre	Value per Acre (dol.)	Quan. per Acre	Value per Acre (dol.)
OPERATING INPUTS:								
Fertilizer								
82-0-0	lb.	0.088	103.000	9.06	103.000	9.06	140.000	12.32
18-46-0	cwt.	10.000	0.880	8.80	0.880	8.80	0.880	8.80
Fertilizer spreader	cwt.	0.125	0.880	0.11				
Insecticide								
Parathion	oz.	0.172	5.000	0.86	5.000	0.86		
Herbicide								
Glean	oz.	16.000	0.083	1.33				
Bladex	lbs.	4.000			2.000	8.00	2.000	8.00
Aatrex	lbs.	2.000			0.500	1.00	0.500	1.00
Landmaster	oz.	0.156					54.000	8.42
Roundup	pt.	12.500			1.000	12.50	1.000	12.50
Lexone or Sencor	pt.	19.000			0.750	14.25	0.750	14.25
Seed	bu.	4.000	1.000	4.00	1.000	4.00	1.000	4.00
Seed Treatment	bu.	1.000			1.000	1.00	1.000	1.00
Fuel	gal.	1.00	6.11	6.11	3.06	3.06	2.42	2.42
Annual Operating Capital	dol.	0.115	23.97	2.76	41.69	4.79	42.42	4.88
Other								
Machinery								
Lube + Repairs	dol.			5.83		4.65		3.99
Custom Harvest								
Base Charge	ac.	12.000	1.000	12.00	1.000	12.00	1.000	12.00
Excess for > 20 bu.	bu.	0.120	23.500	2.82	21.000	2.52	18.600	2.23
Custom Haul	bu.	0.120	43.500	5.22	41.000	4.92	38.600	4.63
Aerial Spray App[b]	ac.	3.340	0.500	1.67	0.500	1.67		
Labor Charges	hr.	4.630	1.137	5.26	0.501	2.32	0.420	1.94
TOTAL OPERATING COSTS ($/acre)				65.83		95.40		102.38
OPERATING COSTS/BUSHEL.				1.51		2.33		2.65

Table 1. (continued)

Machinery and Equipment Ownership Costs:[b]								
Interest at 11.5%	dol.			14.28		10.90		10.00
Depreciation, Taxes, Insur.	dol.			16.53		12.91		11.67
TOTAL OPERATING AND OWNERSHIP COSTS ($/acre)				96.64		119.21		124.05
OPERATING AND OWNERSHIP COSTS/BUSHEL				2.22		2.91		3.21
PRODUCTION:								
Wheat Grain[c]	bu.	2.30	43.50	100.05	41.0	94.30	38.6	88.78
Small Grain Pasture[d]	stkg rt	77.89	0.40	31.16	0.40	31.16	0.40	31.16
TOTAL RECEIPTS ($/acre)				131.21		125.46		119.94
RETURNS ABOVE TOTAL OPERATING COSTS ($/acre)				65.38		30.06		17.56
RETURNS TO LAND, MANAGEMENT, OVERHEAD, AND RISK ($/acre)				34.57		6.25		-4.11

[a] Glean, Bladex, Aatrex, Roundup, Lexone, Sencor, and Landmaster are registered trade names for chlorsulfuron, cyanazine, atrazine, glyphosate, metribuzin, metribuzin, and glyphosate+2,4-D, respectively.

[b] Includes stocker steer enterprise equipment ownership costs.

[c] Average wheat grain yields for the conventional and zero tillage systems are from tillage test plots (September plantings) for years 1982-83 through 1985-86. Wheat grain yields for the one tillage system are the mean of the conventional and zero tillage system grain yields.

[d] The wheat forage price is based upon the gain (value in dollars) of stocker steers on winter pasture from November to March. It is net of all stocker steer operating costs. Stocking density is fixed at 0.4 animals per acre.

Herbicide costs per acre are estimated to be $1.33 for the conventional system, $35.75 for the one tillage system, and $44.17 for the zero tillage system. In general, savings in machinery operating and ownership costs for the alternative systems are insufficient to offset the additional herbicide costs. In addition, average grain yields obtained from September plantings in the experiment station study were higher for the conventional tillage system.

The expected per acre and per farm net returns to land, management, overhead, and risk are reported in table 2. September planting results in the largest expected returns for each of the tillage systems. Similarly, conventional tillage results in greater expected net returns in each planting month than either alternative. As indicated earlier, the stocker activity is expected to generate an additional $23 per acre, or $28,000 per year for the 1,240 acre farm. Use of the winter forage by a supplementary stocker enterprise is an economically important activity. Decision makers who base production decisions solely on the basis of maximizing expected returns, and who are not confronted with soil conservation constraints, would be expected to use conventional tillage, plant in September, and stock for winter grazing.

Stochastic Efficiency Analysis

The application of stochastic dominance to evaluate alternative production strategies has become widely established. Stochastic dominance procedures were formalized by Quirk and Saposnik and have been extended by numerous researchers (Fishburn, Hadar and Russell, Hanoch and Levy, Meyer, King and Robinson). First- and second-degree stochastic dominance are both employed in this analysis.

First-degree stochastic dominance (FSD) involves the simultaneous pair wise comparison of the cumulative distribution functions of net returns for each of the 18

Table 2. Estimated average returns to land, management, overhead, and risk for 18 alternative production systems.

		Expected Return ($/Acre)	Expected Return ($/Farm)
		Wheat Grain Only	
Conventional Tillage			
August	CTAP	30.35	37631
September	CTSP	40.69	50456
October	CTOP	24.54	30423
November	CTNP	-5.17	-6405
One Tillage			
August	1TAP	2.22	2756
September	1TSP	7.90	9796
October	1TOP	-3.52	-4365
November	1TNP	-20.76	-25739
Zero Tillage			
August	OTAP	-6.19	-7676
September	OTSP	-5.03	-6240
October	OTOP	-12.08	-14976
November	OTNP	-22.67	-28108
		Wheat Grain Plus Winter Grazing	
Conventional Tillage			
August	CTAPG	52.96	65670
September	CTSPG	63.31	78498
One Tillage			
August	1TAPG	24.84	30799
September	1TSPG	30.52	37839
Zero Tillage			
August	OTAPG	16.43	20367
September	OTSPG	17.58	21802

alternative production strategies. The risk efficient FSD set includes only one of the 18 production alternatives. The dominant strategy, the strategy which would maximize expected utility for decision makers who prefer more income to less income would be to use conventional tillage, plant in September, and winter graze (CTSPG).

If conventional tillage strategies are eliminated from consideration, the efficient FSD set includes both the August and September one tillage systems with winter grazing (1TAPG, 1TSPG). Similarly, the second degree stochastic dominance (SSD) efficient set contains only the 1TAPG and 1TSPG strategies.

In a recent article, Mjelde and Cochran presented a procedure for determining the amount a decision maker would be willing to pay for the privilege of using a dominant strategy. The mathematics of the methodology are presented in the article and are not repeated here. If soil conservation is ignored and no penalties are imposed, the utility maximizing farmer will use the conventional production system. However, on some soils conventional tillage results in erosion rates which exceed tolerances. Policy makers may elect to levy a fine on the decision maker to ensure the use of a conservation tillage system. (The penalty in current legislation for failure to comply is the lost program benefits.) The Mjelde and Cochran procedure was used to compute the size of the financial penalty which could be levied upon users of the conventional tillage system to shift the dominant strategy (conventional tillage) into the same preference set as the soil conserving (one tillage) conservation compliance strategy.

Expected annual returns from the CTSPG strategy are $78,498 ($63.30 per acre). However, expected returns from the 1TSPG strategy are $37,839 ($30.52 per acre). Lower and upper bounds required to shift the cumulative distribution function of net returns for the conventional tillage system into the same preference set as the one tillage distribution were computed. A fine of $29,571 ($23.85 per acre) applied to the CTSPG strategy is required to shift it into the same FSD preference set as the 1TSPG strategy. However, the decision maker whose utility function is consistent with FSD, may be indifferent between paying the fine and using conventional tillage until the fine was increased to $57,179 ($46.11 per acre). A fine of more than $57,179 would move the CTSPG strategy out of the FSD preference set.

SSD efficient strategies would be preferred by decision makers who are slightly risk averse (Raskin and Cochran). The Mjelde and Cochran procedure was employed to determine that a fine of $37,944 ($30.60 per acre) applied to the CTSPG strategy would move it into the same SSD preference set as the 1TSPG strategy. However, the decision maker whose utility function was consistent with SSD may be indifferent between paying the fine and using conventional tillage until the fine was increased to $44,356 ($35.77 per acre). A fine of more than $44,356 would move the CTSPG strategy out of the SSD preference set and, the risk averse decision maker would switch to the 1TSPG strategy rather than pay the fine and continue to use conventional tillage.

Conclusions

The objective of the research reported in this paper was to determine if two alternative production systems which rely upon herbicides recently registered for use on winter wheat in the Southern Plains are economically competitive with a conventional tillage system. Estimates of expected returns and costs were generated for a conventional (moldboard plow based) system, a one tillage system, and a zero tillage system for each of four alternative planting months (August, September, October, November). Estimates were computed for systems which produce only grain as well as systems in which both wheat grain and livestock gain from winter grazing of the wheat forage are produced. The overall objective was to determine which of the 18 alternative production systems is stochastically efficient.

Grain yields were obtained from an experiment station study. Prices were obtained and estimated net returns to land, management, overhead, and risk were computed. Stochastic dominance criteria were used to determine that the CTSPG strategy from which expected annual returns are $78,498 ($63.30 per acre) dominants all other strategies by FSD.

A fine of more than $35.77 per acre would be required to induce a decision maker whose utility function is consistent with SSD to switch from conventional tillage to a soil conserving one tillage production system. However, a fine of more than $46.11 per acre would be required for decision maker whose utility function is consistent with FSD to induce the decision maker to switch.

An obvious shortcoming of the analysis is that observations from only four growing seasons were used to represent the entire returns distributions. However, only four years of yield data were available. Current wheat plant growth simulation models such as CERES do not include impacts of alternative tillage systems (Ritchie and Otter). Hence, data obtained from the experiment station study were used rather than data generated from a wheat growth simulation model.

A second limitation is that stocking density was assumed constant. In addition, winter grazing was assumed to have no impact on wheat grain yields. Unfortunately, no comprehensive evaluation of the impacts of winter grazing on grain yields is available. It has been hypothesized that yields will not be reduced it the livestock are removed prior to the jointing stage. This hypothesize should be subjected to rigorous testing.

A third limitation is that "intermediate" tillage systems were not considered. In a sense, the budgeted conventional system represents an extreme in terms of tillage intensity.

On the other hand, the zero tillage system is extreme in terms of herbicide intensity. The one tillage system is also herbicide intense and closely resembles the zero tillage system. For monoculture zero tillage or one tillage wheat production to be economical in the region, either a) herbicide pricing strategies will need to be changed or b) alternative, more cost effective herbicides will be required.

At current prices the alternative tillage systems evaluated in this study are not competitive. Additional work is necessary to develop soil conserving production systems which are more economical. The bounding procedure which was employed in this analysis may also be used to evaluate alternative systems.

References

Cochran, Mark J. and Rob Raskin. "A user's guide to generalized stochastic dominance program for IBM PC version GSD 2.1." University of Arkansas, Department of Agricultural Economics Staff Paper SPO688, April 1988.

Fishburn, P. C. Decision and Value Theory. New York: John Wiley and Sons, 1964.

Hadar, J. and W. Russell. "Rules for ordering uncertain prospects." Amer. Econ. Review 59(1969):23-24.

Hanoch, G. and H. Levy. "Efficiency analysis of choices involving risk." Review of Econ. Studies 36(1969):335-346.

King, R. P. and L. J. Robison. Implementation of the Interval Approach to the Measurement of Decision Maker Preference. Michigan State University Research Report 418, 1981.

Kletke, Darrel D. Operation of the Enterprise Budget Generator. Oklahoma State University Research Report P-790, 1979.

Meyer, Jack. "Choice among distributions." J. Econ. Theory 14(1977):326-336.

Mjelde, James W. and Mark J. Cochran. "Obtaining lower and upper bounds on the value of seasonal climate forecasts as a function of risk preferences." West. J. Agr. Econ. 13(1988):285-293.

Quirk, J. and R. Saposnik. "Admissibility and measurable utility function." Review of Econ. Studies 29(1962):140-146.

Raskin, R. and M. J. Cochran. "Interpretation and transformations of scale for the Pratt-Arrow absolute risk aversion coefficient: Implications for generalized stochastic dominance." Western J. of Agr. Econ. 11(1986):204-210.

Ritchie, J. T. and S. Otter. "Description and performance of CERES-Wheat: A user-oriented wheat yield model." In U.S. Department of Agriculture ARS Wheat Yield Project, National Tech. Info Serv. 5285, Springfield, VA, pp. 159-175, 1985.

U.S. Department of Agriculture. Livestock Detailed Quotations. Oklahoma City: Agricultural Marketing Service and the Livestock and Seed Division, 1983-1987.

U.S. Department of Agriculture. Agricultural Prices. Washington: Agricultural Statistics Board Publications, 1983-1987.

Walker, Odell L., Daniel J. Bernardo, James N. Trapp, and Abelardo L. Rodriguez. A Survey of Wheat Pasture Utilization Systems in Western Oklahoma. Oklahoma State University Research Report P-903, September 1988.

Walker, Odell L., Keith S. Lusby, and Wilfred E. McMurphy. Beef and Pasture Systems for Oklahoma: A Business Management Manual. Oklahoma State University Research Report P-888, February 1987.