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CHRIS L. MIKESELL,
JEFFERY R. WILLIAMS,
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JAMES H. LONG*

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Contribution No. 88-4-D from the Kansas Agricultural Experiment Station.

* Graduate Research Assistant, Associate Professor, Department of Agricultural Economics, Kansas State University, Manhattan, Kansas, and Superintendent, Cornbelt Agricultural Experiment Field, Kansas State University, Powhattan, Kansas.

KSU KANSAS STATE UNIVERSITY

Department of Agricultural Economics
Kansas State University, Manhattan, Kansas 66506

Conservation Tillage of Grain Sorghum and Soybeans: A Stochastic Dominance Analysis

by

Chris L. Mikesell, Jeffery R. Williams, and James H. Long

The authors are Graduate Research Assistant, Associate Professor, Department of Agricultural Economics, Kansas State University, Manhattan, Kansas and Superintendent, Cornbelt Agricultural Experiment Field, Kansas State University, Powhattan, Kansas.

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ABSTRACT

Three tillage systems: conventional tillage, ridge tillage and no-tillage are evaluated using stochastic dominance with respect to a function analysis. Each tillage system is evaluated for three cropping patterns: continuous grain sorghum, continuous soybeans, and soybeans after grain sorghum. Conventional tillage continuous grain sorghum would be preferred by risk averse managers, although small changes in production costs and yield differences could lead to indifference between a no-tillage system and the conventional tillage system.

Key words: conservation tillage, risk, stochastic dominance, grain sorghum, soybeans.

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INTRODUCTION

This study provides an economic analysis of two conservation tillage systems for grain sorghum and soybeans, ridge-till and no-till, and compares them with a conventional tillage system for an area typical of the western corn belt and eastern Great Plains. The major objective of this study is to determine the most economical production system for an area not completely comparable to the sub-humid corn belt or the semi-arid region of the Great Plains. This study will limit its consideration to three cropping systems for each of the tillage methods: continuously cropped grain sorghum, grain sorghum grown after soybeans, and continuously cropped soybeans. These systems were studied at the Cornbelt Experiment Field, located in north-eastern Kansas, for the years 1975 through 1984. The risk effect of the selected tillage and rotational practices are studied by examining annual net return variability. First degree stochastic dominance (FSD), second degree stochastic dominance (SSD), and stochastic dominance with respect to a function (SDWRF) are used for selecting risk efficient tillage systems.

The effect of conservation tillage upon net returns has been examined by several studies. Conservation tillage appears to have little short-run advantage over conventional tillage systems in many areas with sub-humid climates. Duffy and Hanthorn found that returns to conservation tillage strategies were not significantly different for U. S. corn farmers or Midsouth and Southeast soybean farmers in 1980. In the Midwest, conventional-till soybean farmers accrued significantly higher returns than no-till soybean farmers, primarily as a result of higher yields.

Other studies for the corn belt have shown that declines in production expenses because of lower fuel, repair, and capital costs may be largely offset by increases in chemical costs for most crops, including corn, soybeans, grain sorghum, and wheat (Klemme, 1983; Duffy and Hanthorn; Brady; Johnson et al.). A common conclusion among these and other studies is that farm-level economic feasibility of reduced tillage systems depends, in large part, on managerial skills necessary to obtain yield levels at least equal to and possibly greater than those from established, conventional tillage systems.

In semi-arid climates, conservation tillage performs better. Reed and Erickson found that conservation tillage had consistent yield advantages over conventional tillage for wheat in Kansas and northeast Colorado and grain sorghum in Kansas and Nebraska. It is believed that the major contributing factor to increased yields is increased soil moisture. Williams examined dryland tillage systems with wheat and grain sorghum in the Great Plains. The study found that managers classified as risk averse prefer conservation tillage systems for wheat and grain sorghum instead of the traditional, conventional, wheat-fallow cropping system. Higher yields in association with reduced energy and labor costs offset increased chemical costs of the conservation systems.

TILLAGE PRACTICES

The cropping systems considered in this study are: conventional tillage continuous grain sorghum (CVGG), conventional tillage soybeans after grain sorghum (CVGS), conventional tillage continuous soybeans (CVSS), ridge-till continuous grain sorghum (RTGG), ridge-till soybeans after grain sorghum (RTGS), ridge-till continuous soybeans (RTSS), no-till continuous grain sorghum (NTGG), no-till soybeans after grain sorghum (NTGS), and no-till continuous soybeans (NTSS).

The no-till system studied allows planting to be done without disturbance of the residues from the previous crop. Since no pre-plant tillage is used, weed control must be achieved through use of herbicides between crop years and during the crop growing season. Cultivation may be used to supplement herbicides for added weed control only during the cropping season, not between crop years.

In the ridge-till system, crops are planted on non-tilled ridges formed by the previous year's cultivation. Complete weed control, prior to planting, is less critical in ridge-till systems as compared to no-till, because weeds in the seed furrow are physically eliminated during planting. This feature reduces weed-management variability problems and allows reduced use of herbicides. Because cultivation and ridging provide weed control between rows, ridge-till systems are suitable for banding of herbicides at planting. However, plots in this study maintained the same levels of herbicides used for the no-till systems; banding was not used.

The ridge-till and no-till systems reduce the number of tillage operations for continuous grain sorghum, grain sorghum-soybeans, and continuous soybeans by 3.0 operations. The no-till and ridge-till systems each require 2.0 herbicide applications for each crop, which is double the number required in the conventional tillage system. Total acreage covered is reduced in the no-till and ridge-till systems for each crop: 26% for continuous cropped grain sorghum, 28% for grain sorghum and soybeans in rotation, and 29% for continuously cropped soybeans.

PROCEDURE

Stochastic dominance analysis is used to select the most efficient strategies (cropping systems in this instance) by comparing cumulative probability distributions of possible incomes for each strategy. Stochastic dominance does not require that the underlying distribution be normal and, therefore, is more flexible than EV analysis. Cochran, Robison, and Lodwick present an excellent review of five stochastic dominance efficiency criteria. In this study, stochastic dominance with respect to a function (SDWRF), a generalized version of first and second degree stochastic dominance criteria, is used. SDWRF is more flexible and discriminating and does not require the specification of the decision maker's utility function.

SDWRF criteria order choices for decision makers facing uncertainty by setting upper and lower bounds to define an interval, using the Pratt absolute risk aversion function R(x). The absolute risk aversion function is defined by Pratt as

$$R(x) = -U''(x)/U'(x),$$

which is the ratio of derivatives of the decision maker's utility function U(x). The SDWRF classes of utility functions can be established by using risk preference intervals bounded by a lower risk aversion coefficient $R_1(x)$ and an upper risk aversion coefficient $R_2(x)$.

Seven, selected, absolute, risk-aversion, coefficient intervals were used for the SDWRF analysis (Table 3). The intervals for the SDWRF analysis were arbitrarily assumed. King and Robison suggested that most intervals should be established within the range of -.0001 to .0010. Risk neutral behavior would generally be exhibited within the range of -0.00001 and 0.00001. Those above this range would exhibit more risk-averse behavior (those within .00005 to .0001 would be considered strongly risk averse), whereas those below would exhibit more risk-seeking behavior. The solutions for the risk-aversion intervals were found using an optimal control algorithm developed by Raskin, Goh, and Cochran.

DATA

Variable inputs and general equipment requirements were determined for each cropping system, based on agricultural experiment station practices. Variable and fixed costs for 1985 with regard to a case farm size, tenure arrangements, and debt characteristics were estimated and organized in a whole farm enterprise budget. Specifically, costs by individual field operation were estimated and aggregated into an enterprise budget with other costs not specific to individual field operations to determine the expected returns per acre.

Yields and Prices

Crop prices used are the season averages from the northeastern district of the Kansas Crop and Livestock Reporting Service from 1975-1984. Yield data for grain sorghum and soybeans were obtained from the Corn Belt Experiment Field in northeast Kansas for the same 10-year period. Analysis of variance procedure was used to determine if the mean yield of each cropping system was significantly different. No significant difference in yields was detected at the $\alpha = 0.05$ level.

Establishing Farm Size and Tenure

Data from 230, predominantly cash crop, dryland farms in the Northeast Kansas Farm Management Association were used to establish the size and tenure arrangements of the case farm. Owned land in the Northeast Association was approximately 31% of the farmers' total acreage. The case farm's enterprise budgets assume that 30% of the land is owned (192 acres) and 70% is rented (448 acres), for a total of 640 acres.

Machinery, Fuel and Labor Requirements

Tillage implement sizes take into account available work days, acres, equipment efficiency, and hours/day available for field work. Tractor horsepower requirements are based on the draft requirements of the implements and available field work days, with an average annual probability of completing the field work 85 percent of the time within the available or suggested work period (Buller et al.; Schrock). Fuel requirements are based on data from an energy use by tillage operation study conducted by Schrock, Kramer, and Clark. This study estimated average fuel use per acre for specific tillage operations that are used in the cropping systems. Labor requirements are estimated based on acres per hour that can be covered with the equipment complement available and the total acres that need to be covered per operation.

Equipment values for depreciation calculations are based upon 85% of list price. All equipment ages were assumed to be half of their listed depreciable life: tractors and combines--5 yrs., planters--6 yrs., tillage implements--7 yrs., and list prices were deflated to the appropriate year that the machine would have been purchased to figure the original value for depreciation purposes. Salvage values are estimated to be a percentage of purchase price (Hoag et al.). Repair costs are estimated using a method described by Rotz. All equipment needed that would not exist in a conventional grain sorghum-soybean cropping system was assumed to be newly purchased. Only equipment that would already be in a conventional grain sorghum-soybean system was assumed to be used.

ANALYSIS

The results of the analysis from comparison of average net returns using 1985 cost of production estimates with a 10-year average price and yield of each cropping system are summarized in Table 1. Net return to management is slightly higher for the no-till continuous grain sorghum system than for the conventional tillage grain sorghum system. Since the no-till continuous grain sorghum system did not have a lower standard deviation than the conventional tillage grain sorghum system (Table 2), from an expected value-variance risk standpoint, no system stands out as the preferred system. The conventional tillage continuous grain sorghum system had the second lowest standard deviation, lowest coefficient of variation, and the smallest single year loss of any system. The no-till continuous grain sorghum system had the highest single return of $58,708 and the highest average net return to management. The no-till system had the largest annual losses and the highest standard deviations of the systems with either continuous grain sorghum or a grain sorghum soybean-rotation.

Stochastic dominance analysis was used to find the FSD, SSD, and SDWRF efficient sets (Table 3). No system dominated all others by first degree criteria. The conventional tillage and no-till continuous grain sorghum systems were second degree efficient. Further analysis using risk-aversion intervals (SDWRF) determined that the no-till continuous grain sorghum (NTGG) would be preferred by risk-seeking managers, whereas risk-averse individuals would prefer the conventional continuous grain sorghum system (CVGG).

The magnitude of a parallel shift of the dominant distribution (CVGG) that is necessary to eliminate its dominance and produce an efficient set containing both the previously dominant distribution and the specified alternative was identified. In the interval (0.00001 to 0.00005), which applies to individuals with moderate risk aversion, the results are particularly sensitive to production costs or yield differences between the conventional-till and no-till continuous grain sorghum systems. If the cumulative probability distribution for the CVGG is lowered by a parallel shift of $375, it no longer dominates the no-till continuous grain sorghum system (NTGG). This is equivalent to a $0.59 per acre increase in cost or a .25 bushel per acre decrease in the yield in the CVGG system (Table 4). For the more strongly risk-averse interval (0.00005 to 0.0001) the CVGG distribution must be shifted by $4,400 and by $5,500, respectively, for the NTGG and ridge-till continuous grain sorghum systems (RTGG) to be in the efficient set.

When alternative strategies are not mutually exclusive but can be combined to form additional portfolio strategies, stochastic dominance procedures may not correctly determine all the efficient strategies. McCarl et al. provided a test that compares the correlation coefficients of the strategies to the ratio of their standard errors minus a correction for the difference between their means. If the correlation coefficients are less than the ratio, then diversification among the strategies should be considered.

When this criterion was considered, the test indicated that diversification could take place between CVGG and CVSS. (Diversification with NTSS and RTSS was also indicated, but this strategy was deemed infeasible because of equipment limitations.) A combination of 90% of the acreage as CVGG and the remaining 10% as CVSS was found to be SSD efficient; however, a combination of 80% CVGG and 20% CVSS was not SSD efficient. Neither combination appeared in the efficient set for the risk-averse intervals (0.00001 to 0.00005) and (0.00005 to 0.0001), when a SDWRF criterion was selected.

Many farmers in eastern Kansas employing ridge-till systems use band application of herbicides when planting instead of broadcasting the chemical. Provided weed control is maintained by the cultivation operation, there should be no difference in yields from systems using broadcast application. This cultivation operation is included in the ridge-till systems of this study. When band application at planting was assumed, herbicide costs were reduced $2,944 in the RTGG system, $3,942 in the RTGS system, and $4,939 in the RTSS system. However, this cost reduction was not enough to affect the selection of the best tillage system in any risk aversion-interval.

A major advantage of ridge-tillage is the physical elimination of weeds in the crop row at planting. This could provide for the elimination of preplant herbicides. Janssen and Regehr found that in eastern Kansas, when no preplant herbicide treatments were used in conjunction with band application of herbicides, yields were reduced an average of 13 bushels per acre in grain sorghum and 3 bushels per acre in soybeans. The results in our study were reevaluated after adjusting the original ridge-tillage data for reduced herbicide costs and reduced yields. The average net return increased for all the ridge-tillage systems (Table 2). However, the net return did not increase enough to change the SDWRF results.

The continuous soybean systems showed the worst performance among the cropping strategies. The diversified grain sorghum-soybean cropping strategies had lower average net returns by approximately 50%, when compared with their continuous grain sorghum cropping system counterparts. Yields for sorghum in this study (Table 2) are on average approximately 20 bushels per acre greater than farm yield in the same area. Schurle reported that the mean yield for dryland grain sorghum in the same county in which the experiment field is located was 77.28 bu. from 1974-1983. The standard deviation was 19.45. The higher yield on the experiment field plots is generally attributed to an application rate of nitrogen fertilizer 40 lbs/acre higher than is typical of farm practices. Vigil et al. and Janssen and Regehr reported grain sorghum yields and nitrogen application rates similar to those used in this study at two other experiment fields in northeast Kansas. Average soybean yield and standard deviation reported by Schurle are quite similar to the ones in this study, 31.55 bu. and 9.11, respectively.

After adjusting the net return distribution of the cropping systems containing grain sorghum, to include 20 bu./acre decrease in grain sorghum yield and a 40 lbs./acre decrease in the application rate of nitrogen fertilizer, the efficient sets of the SDWRF analysis changed. In the moderately risk-averse interval, no-till grain sorghum-soybeans joined the CVGG system. Reductions in costs of $1.09/acre in RTGS and $1.56/acre in CVGS would also add them to the efficient set. In the more highly risk-averse interval, the CVGG system was individually selected.

Soil Loss Value

The basic objective of conservation tillage techniques such as no-tillage is to reduce soil erosion. The value of soil saved by reduced erosion, whether it is derived from added yield in the short run, long-run preservation of productivity, or prevention of off-site costs of soil erosion, is difficult to determine. Many benefits of soil erosion prevention are not captured by the manager or have limited relevance to short-run decisions concerning tillage methods. Unless managers place intrinsic value on soil in their short-run decision-making process, conservation tillage systems that do not generate economically equivalent or improved returns will not be adopted. Such is the case in this short-run farm-level study, when soil value is not considered.

Although it is difficult to determine the value of soil lost, a percentage yield loss in the SDWRF dominant (CVGG) system that would generate an annualized present value of yield loss over a specified planning horizon can be estimated, causing a selected conservation tillage system to be economically equivalent. This annualized present value of yield loss can be interpreted as the soil loss value.

Previously, sensitivity analysis was performed to determine the parallel shift required in the dominant distribution (CVGG) to remove dominance over the other systems (Table 4). These values can be interpreted as the soil loss value per acre that makes the CVGG system equivalent to the conservation tillage systems. For example, if the cost of the CVGG system increased $8.13/acre (Table 4), it would be equivalent to the RTGG system in the SDWRF interval (0.00001 to 0.00005). If we assume that $8.13/acre is the annualized present value of yield loss (soil value) that results from added soil erosion in the CVGG system in comparison to the RTGG system over a 30-year planning horizon, the percentage yield loss required to make the system equivalent is .2709% annually or 8.48% over the entire 30 years (Table 5). Similar estimates are also reported in Table 5 that make the CVGG system equivalent to the NTGG, RTGG, and NTGS systems over 30- and 50-year planning horizons, given real discount rates of 3% and 5%.

Comparisons of these yield loss estimates can be made with yield loss figures from national and regional studies, although caution should be used for individual cases because relationships between crop yields and soil erosion can be highly site specific. Larson et al. estimated that accumulated yield reductions of 2% would occur over a 50-year planning horizon for all cropland in the Major Land Resource Area (MLRA) 107, which includes part of northeast. Crosson and Stout also reported a 4% yield trend reduction over a 30-year period for corn production in the corn belt and northern Great Plains. Given this range, the NTGG system could be the preferred system, since the soil losses required for NTGG to dominate CVGG are less than 2% at any of the combinations of discount rate and planning horizon. A 4% yield reduction over a 30-year period would be equivalent to an annualized present value of yield loss in this study at a 3% real discount rate of $3.96/acre. This number can be compared to the numbers in Tables 4 and 5. Much higher yield losses would be required in the CVGG system to make conservation tillage systems other than the NTGG system feasible. Highly risk-averse individuals would require yield losses significantly greater than those likely to make any of the conservation tillage systems feasible.

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Table 1. Income, Returns, and Selected Costs by Cropping System.[a]

INCOME & COSTS	CROPPING SYSTEM[b]								
	CVGG	RTGG	NTGG	CVGS	RTGS	NTGS	CVSS	RTSS	NTSS
Gross Income	148298	145101	149275	131655	136488	133738	114766	113692	116040
Variable Costs									
(Owned Land)	18887	22328	22077	17377	20830	20584	15867	19331	19091
(Rented Land)	32373	36683	36051	30726	35064	34376	29080	33445	32837
Fixed Costs									
(Owned Land)	16668	15739	14726	16668	15739	14726	16668	15739	14726
(Rented LAnd)	62157	59094	57899	57497	56683	53549	52768	50300	48593
Total Cost	130085	133845	130753	122269	129095	128316	114383	118813	115247
NET RETURN	18213	11256	18522	9386	8173	10552	383	-5123	793
Labor	2983	1993	1993	2818	1852	1852	2653	1711	1711
Fuel/Oil	2949	1648	1648	2813	1512	1512	2676	1376	1376
Chemical Cost	14205	23143	23252	13453	22391	22391	12701	21638	21748
SUBTOTAL	20137	26785	26894	19084	25755	25864	18030	24725	24834
Fertilizer	13903	13903	13903	10146	10146	10146	6388	6388	6388
SUBTOTAL	34041	40688	40797	29229	35900	36010	24418	31113	31223
Repair	9469	8121	7186	9362	8026	7108	9255	7932	7030
Depreciation	14164	12736	11186	14164	12736	11186	14164	12736	11186
Interest	13399	11939	10340	13399	11939	10340	13399	11939	10340
Total	71073	73483	69509	66155	68601	64535	61237	63720	59778

[a]Based on mean 10-year yields and prices and 1985 production costs.

[b]CVGG --- Conventional Tillage Continuous Grain Sorghum
RTGG --- Ridge Tillage Continuous Grain Sorghum
NTGG --- No Till Continuous Grain Sorghum
CVGS --- Conventional Tillage Soybeans after Grain Sorghum
RTGS --- Ridge Tillage Soybeans After Grain Sorghum
NTGS --- No Till Soybeans After Grain Sorghum
CVSS --- Conventional Tillage Continuous Soybeans
RTSS --- Ridge Tillage Continuous Soybeans
NTSS --- No Till Continuous Soybeans

Table 2. Risk Analysis and Yield Statistics.

	CROPPING SYSTEM[a]								
NET RETURN VARIABILITY[b]	CVGG	RTGG	NTGG	CVGS	RTGS	NTGS	CVSS	RTSS	NTSS
Mean	16182	10114 (11053)	16918	7170	6345 (10980)	8709	-2092	-7393 (939)	-1870
Std. Dev.	21120	19578 (18664)	26285	23391	21348 (21272)	23585	26141	23404 (23796)	24866
Coeff. Var.	1.31	1.94 (1.69)	1.55	3.26	3.36 (1.94)	2.71		--- (25.34)	
Minimum	-6345	-11143 (-9385)	-21296	-17965	-17197 (-14999)	-18868	-41942	-43435 (-37302)	-39930
Maximum	48621	39286 (39648)	58708	42370	35289 (39194)	41885	30314	19403 (28361)	28743
Tot. Neg.	8658	33574 (24621)	31781	58360	61006 (37008)	58484	126595	141136 (100142)	116856
Yrs. Neg.	2	5 (3)	3	6	5 (5)	5	5	5 (5)	5
YIELD DATA (bu./acre)									
Sorghum									
Mean	100.2	98.0	100.3	98.8	103.0	102.0			
Std. Dev.	22.2	17.0	24.6	26.2	21.4	23.6			
Soybean									
Mean				29.4	30.3	29.3	28.8	28.6	29.2
Std. Dev.				10.2	9.5	9.4	10.2	9.2	10.1

[a]CVGG --- Conventional Tillage Continuous Grain Sorghum
RTGG --- Ridge Tillage Continuous Grain Sorghum
NTGG --- No Till Continuous Grain Sorghum
CVGS --- Conventional Tillage Soybeans after Grain Sorghum
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NTGS --- No Till Soybeans After Grain Sorghum
CVSS --- Conventional Tillage Continuous Soybeans
RTSS --- Ridge Tillage Continuous Soybeans
NTSS --- No Till Continuous Soybeans

[b]Numbers in parenthesis are for results when no preplant herbicide treatments are used in conjunction with band application of herbicides in the ridge tillage systems.

Table 3. SDWRF Results.

	Lower R(x)	Upper R(x)	Base Case Dominant Systems	Adjusted Yield Dominant Systems[b]
FSD	- ∞	+ ∞	CVGG NTGG RTGG NTGS RTGS	CVGG NTGG CVGS NTGS RTGS CVSS NTSS
SSD	0	+ ∞	CVGG NTGG	CVGG CVGS NTGS RTGS
SDWRF				
	-0.00005 to	-0.00001	NTGG	NTGG NTGS CVSS
	-0.00001 to	0.0	NTGG	NTGS
	0.0 to	0.00001	CVGG NTGG	NTGS
	-0.00001 to	0.00001	CVGG NTGG	NTGS
	0.00001 to	0.00005	CVGG	CVGG NTGS
	0.00005 to	0.0001	CVGG	CVGG
	0.0001 to	0.001	CVGG	CVGG

[a]CVGG --- Conventional Tillage Continuous Grain Sorghum
RTGG --- Ridge Tillage Continuous Grain Sorghum
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NTGS --- No Till Soybeans After Grain Sorghum
CVSS --- Conventional Tillage Continuous Soybeans
RTSS --- Ridge Tillage Continuous Soybeans
NTSS --- No Till Continuous Soybeans

[b]Grain sorghum net return distribution has been adjusted to include a 20 bu./acre decrease in yield and a 40 lbs./acre decrease in nitrogen fertilizer use.

Table 4. Sensitivity Analysis of SDWRF Results

Dominant System	Compared System[a]	Decrease In Net Return Of Dominant System[b]	Cost Per Acre	Bushels Per Acre
Interval $R_1(x) = 0.00001$, $R_2(x) = 0.00005$				
CVGG	NTGG	375	0.59	0.25
CVGG	RTGG	5,200	8.13	3.52
CVGG	NTGS	8,000	12.50	5.41
CVGG	CVGS	9,500	14.84	6.43
CVGG	RTGS	9,700	15.16	6.56
CVGG	NTSS	19,000	29.69	12.85
CVGG	CVSS	19,500	30.47	13.19
CVGG	RTSS	23,800	37.19	16.10
Interval $R_1(x) = 0.00005$, $R_2(x) = 0.0001$				
CVGG	NTGG	4,400	6.88	2.98
CVGG	RTGG	5,500	8.59	3.72
CVGG	NTGS	10,100	15.78	6.83
CVGG	CVGS	10,800	16.88	7.31
CVGG	RTGS	10,900	17.03	7.37
CVGG	NTSS	23,100	36.09	15.63
CVGG	CVSS	24,700	38.59	16.71
CVGG	RTSS	27,700	43.28	18.74

[a]CVGG --- Conventional Tillage Continuous Grain Sorghum
RTGG --- Ridge Tillage Continuous Grain Sorghum
NTGG --- No Till Continuous Grain Sorghum
CVGS --- Conventional Tillage Soybeans after Grain Sorghum
RTGS --- Ridge Tillage Soybeans After Grain Sorghum
NTGS --- No Till Soybeans After Grain Sorghum
CVSS --- Conventional Tillage Continuous Soybeans
RTSS --- Ridge Tillage Continuous Soybeans
NTSS --- No Till Continuous Soybeans

[b]The decrease in net return is the magnitude of the parallel shift of the dominant distribution (CVGG) that is necessary to eliminate its dominance over the indicated system.

Table 5. Annual Percentage Yield Loss Per Acre[a]

Real Discount Rate	Cropping System and Annualized Present Value Difference ($/acre)[b]					
	NTGG - $0.59		RTGG - $8.13		NTGS - $12.50	
	30 yr	50 yr	30 yr	50 yr	30 yr	50 yr
3%	.0193	.0131	.2709	.1848	.422	.2881
	(0.58)	(0.66)	(8.48)	(9.68)	(13.52)	(15.52)
5%	.0215	.0159	.3016	.2232	.4701	.3483
	(0.65)	(0.80)	(9.48)	(11.82)	(15.18)	(19.06)

[a]Annual percentage yield loss over a 30- and 50-year planning horizon required to reduce the conventional continuous grain sorghum system (CVGG) annualized return advantage to zero, when compared with the indicated conservation tillage systems. Numbers in parenthesis are the total percentage yield reduction required over the planning horizon.

[b]The annualized present value difference is the magnitude of the parallel shift of the SDWRF dominant distribution (CVGG) that is necessary to eliminate its dominance in the interval (0.00001, 0.00005) over the indicated system. It is also interpreted as the annualized present value of yield loss from added soil erosion, which results from the estimated annual percentage yield reduction over the planning horizon.

$$APV = \frac{r}{1-(1+r)^{-s}} \quad P \sum_{t=1}^{s} \left[\left(\sum_{t=1}^{s} YX^{t}\right)/(1+r)^{t}\right]$$

where:

APV = annualized present value of yield loss
r = real discount rate (.03, .05)
s = years in planning horizon (30, 50)
P = real price of grain sorghum ($2.31)
Y = base yield in year 0. (100 bu/acre)
X = annual percentage yield loss

NTGG --- No Till Continuous Grain Sorghum
RTGG --- Ridge Tillage Continuous Grain Sorghum
NTGS --- No Till Soybeans After Grain Sorghum