Economics of Yield and Returns Variability with Dryland Cotton Cropping Systems

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ABSTRACT

Cotton production in the Texas High Plains region accounts for 15 to 18% of the total cotton production in the United States. About half of the cotton in this region is grown under dryland conditions. Although much of the cotton in the region is produced using a conventional tillage cropping system, several alternative cropping systems are becoming increasingly accepted. The objective of this study was to evaluate the relative economic performance of the conventional tillage dryland cotton production system and several conservation tillage dryland cotton production systems on the Texas High Plains. The net economic returns to six feasible dryland cropping systems were ranked using stochastic dominance with respect to a function. Four conservation cropping systems (reduced tillage continuous cotton, wheat-cotton reduced tillage, sorghum-cotton reduced tillage, and no-till continuous cotton) are confirmed to be superior to the widely accepted conventional cotton cropping system. These four conservation systems increased stability and profitability over the conventional tillage system. Hence these alternatives are options that producers should consider as conservational tillage systems in dryland cotton production and may be better suited to producer risk preferences than conventional practices.

KEYWORDS: wheat, sorghum, stochastic dominance

The Texas High Plains (THP) is a 25-county semi-arid region in northwest Texas with annual average rainfall of 471 mm and a frost-free growing season of 153 days. Cotton is the most economically important agricultural product originating in the area. Around 7.5 million hectares of cotton are planted each year in the Texas High Plains (Texas Agricultural Statistics Service, 1994). Approximately half the cotton area is farmed dryland without irrigation. Average economic returns have historically been greater from cotton than from other agronomic crops, inducing a gradual shift of most of the agricultural resources toward a conventional tillage cotton monoculture.

Conventional tillage production generally follows the order of operations listed in Table 1. Following harvest, cotton stalks are destroyed, followed by a deep tillage operation. Before planting in the spring, herbicide and fertilizer are

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incorporated and beds are formed. Planting and cultivation begin in May. The growing season extends throughout the summer and fall, and cotton is typically harvested in October or November. Prior to harvest, about ten field operations are performed.

Fewer operations are included in the alternative tillage systems. The operations in a representative crop season are listed in Table 1. The crop is planted into the residue of the previous crop, and additional herbicides are used for weed control, eliminating some of the tillage practices. Through the elimination of many of these operations, production costs such as labor, fuel, and machinery costs are lowered.

Conservation tillage systems generally provide benefits such as conservation of soil moisture and reduction of soil erosion from wind and water. Several studies have substantiated these benefits. A study by Unger et al. (1991) found that although no-tillage changed the distribution of organic matter and some plant nutrients in the soil, changes were relatively small and no-tillage appeared to be a viable cropping practice for conserving soil and water and maintaining crop productivity on dryland in the southern Great Plains. Likewise, a study by Eck and Jones (1992) found that conservation tillage practices reduced soil erosion and increased precipitation storage efficiency. Additionally, Wagger and Denton (1989) found that corn and soybean yield increases were attributed primarily to greater soil moisture availability as a result of reduced runoff using no-tillage.

Resulting from emphasis on conservation in government agricultural policy, conservation tillage systems have received increased attention from producers in the THP. However, like all aspects of agricultural production, widespread acceptance of conservation tillage practices for cotton in the region depends on the relative long-term profitability of each system as compared to feasible alternatives. Harman et al. (1989) found support for conservation's profitability when it was determined that although herbicide costs were greater than with no-tillage, long-term annual profit of cotton on the southern High Plains with no-tillage increased \$82 ha^{-1} over conventional tillage because of increased yield and lower machinery depreciation costs. Further, in a study of no-tillage versus conventional tillage, Bordovsky et al. (1994) found that no-tillage significantly increased total revenue by increasing lint yields of cotton 6.9 and 5.5% for dryland and irrigated, respectively. Likewise, Morrison et al. (1990) found that, under no-tillage practices, soil is protected, resource use is lowered, and crop yields are maintained. All these studies indicated that profitability is attainable with conservation techniques, thus providing a viable alternative for producers. The objective of this study was to evaluate the relative economic performance of the conventional tillage dryland cotton production system and several conservation tillage dryland cotton production systems on the THP.

MATERIALS AND METHODS

In 1987, long-term dryland cropping systems experiments were established at the Texas Agricultural Experiment Station at Lubbock, TX. The soil type at the experimental site is an Acuff loam (fine-loamy, mixed, thermic Aridic Paleustolls) with 50% sand, 21% silt, and 29% clay with a pH of 7.8. Experiments were conducted on 7.9 m by 15.2 m randomly arranged plots. Treatments (cropping systems) included conventional tillage system in continuous cotton and five

Table 1. Cropping system practices at the Texas Agricultural Experiment Station, Lubbock, TX.

Conventional	Reduced	No till	Terminated Wheat/Cotton	Sorghum/ Cotton	Wheat/ Cotton
Shred stalks	Shred stalks	Apply 2,4-D & diuron	Plant wheat	Apply 2,4-D & diuron	Apply 2,4-D & diuron
Disc					
Disc in trifluralin & fert.	List in trifluralin & fert.			Apply glyphosate & diruon	
Plant	Plant & apply caparol	Plant & apply prometryn, glyphosate, metolachlor, & caparol	Plant & apply prometryn, glyphosate, metolachlor, & caparol	Plant & apply caparol, glyphosate, & Dual	Plant & apply caparol, glyphosate, & Dual
Rotary hoe	Rotary hoe	Rotary hoe			
Cultivate 3 times	Cultivate 1 time	Cultivate 1 time	Cultivate 1 time	Cultivate 1 time	Cultivate 1 time
Harvest	Harvest	Harvest	Harvest	Harvest	Harvest

alternative tillage cropping systems: reduced tillage system in continuous cotton, no-tillage system in continuous cotton, reduced tillage cotton system with terminated wheat cover crop, a reduced tillage cotton rotation with sorghum, and a reduced tillage cotton rotation with wheat. Cropping and tillage systems were initiated in 1987, and data used in this study were collected for the crop years 1988-1994. Prior to the establishment of these cropping system plots, the area had been in continuous cotton production for five years.

In conventional-tillage continuous cotton, standard land preparation, herbicide, and tillage practices were used (Table 1). In the reduced till continuous cotton, deep tillage was eliminated and trifluralin was incorporated in the bedding operation. In no-till continuous cotton, the crop was planted into the old stalks without any tillage. Winter weeds were controlled with an early preplant application of 2,4-D + diuron. Glyphosate was applied at planting as a burn-down to emerged weeds and metolachlor + prometryn was applied pre-emergence. Similar herbicide treatments were used on the wheat-cotton, and sorghum-cotton rotations. In the terminated wheat-cotton system, wheat was drilled into the cotton stalks after harvest as a winter cover crop. The wheat was terminated with glyphosate at 0.43 kg ha^{-1} in April.

Fertilizer applications were based on yearly soil tests of each plot. Fertilizer applications were 22 to 33 kg N ha^{-1} and 22 kg P ha^{-1} for dryland cotton. Cotton lint yield was determined by harvesting and ginning 4.0 m of two rows from each plot. Gross returns per hectare were calculated as lint yield times the market price and did not reflect government deficiency payments. Total costs of production were separated into two components: preharvest and harvest costs. Because harvesting costs are a function of actual cotton yields, they varied across cropping systems. Cost of mechanical operations were based on the Texas crop enterprise budgets (TAES, 1994). Variable input costs were based on local prices for seed, fertilizer, herbicide, and irrigation.

Behavior and patterns of average yields and returns provide the producer with useful tools for production planning; however, only the variability of yields and returns allows the producer to examine the relative risk associated with particular cropping practices. To accommodate the need for a valuation of relative risk, the stochastic dominance with respect to a function (SDRF) technique was used, King and Robison (1981). The SDRF is a valuative criterion that orders variable alternatives for a defined set of decision makers who have an absolute risk aversion coefficient that falls between specified upper and lower bounds. The absolute risk aversion coefficient (ARAC), defined as the negative ratio of the second derivative of a von Neumann-Morgenstern utility function to the first derivative of the same function, is a measure of the degree of convexity or concavity of the decision maker's utility function. Since the slope of a utility function is accepted to be positive, a positive ARAC suggests the second derivative is negative, indicating a concave utility function. Accordingly, the absolute risk aversion coefficient serves as a suggestion of the risk preference for the decision maker. Because the absolute risk aversion coefficient is a unique measure that holds across preferences and the utility function is unique only to a positive linear transformation, the former provides a less restrictive measure of risk preference. A major advantage of SDRF as a valuation criterion is that it imposes no limitations on the upper or lower bounds of the absolute risk aversion interval. The interval can be specified as small or large as necessary to account for the uncertainty in the approximation of the coefficient.

Formally, the SDRF method designates a necessary condition that ensures the domination of one distribution over another for a given range of absolute risk aversion. Given two distributions, ***A*** and ***B***, the necessary condition for the dominance of distribution ***A*** over distribution ***B*** is that the area in the limit, as the X variable approaches $+\infty$, above the cumulative distribution function of distribution ***A*** be greater than the same for the cumulative distribution function of distribution ***B***.

Yield data points were taken from three plots of each cropping system for each of the six sample years. Therefore, eighteen yield data points were used along with costs of production and revenues specified in 1993 values to find eighteen net revenue calculations for each cropping system. Following King and Robison, (1981), the SDRF technique was used to compare the net revenues given alternative absolute risk aversion intervals. Three risk aversion intervals were specified. The intervals span the range of the absolute risk aversion coefficient from -.0003 to .0006. SDRF was performed for each interval.

RESULTS AND DISCUSSION

Dryland cotton lint yields exhibit wide fluctuation relative to rain patterns during the growing season. Table 2 summarizes the overall average and standard deviation of cotton yields for each of the six cropping systems.

Monthly rain for each year is found in Table 3. Rain in four of the six years is below the 75-yr. average, with three of those years enduring a below average measure of at least 76 millimeters. In spite of low rain in 1988, yields were above average for all systems except the sorghum-cotton rotation, resulting from acutely dry conditions throughout most of the rest of the sample period reducing the overall average.

Severely dry conditions in 1988 and 1989 lead to below average yields in 1989 for all systems except for the wheat-cotton rotation. Rain for 1990 was below average; however, timely rains in April and through the last part of the summer lead to above average yields for all systems except reduced tillage in that year.

Annual rain in 1991 exceeded the long-run average by over 75 mm due to heavy rains in September. The September rainfall was over 76 mm above the 75-year average, leading to extremely wet conditions late in the growing season when excessively wet conditions are detrimental to yield. As a result, the yields for all systems in 1991 were below the sample average. However, average yields for all the cropping systems were well above the sample average, resulting from significant and timely rain throughout the growing season in 1992.

Cotton yields in 1993 for the continuous cotton systems were significantly below sample averages, while yields for the two cotton rotations were higher than average. Above average precipitation during the last two months of 1992, resulting in good residual moisture on the rotation systems accounted for the yield differential.

Average net revenues for each system for the six year sample are found in Table 4. Revenues in Table 4 do not reflect government deficiency payments. Slight variations in the price of cotton existed across systems resulting from differences in fiber quality. The values in Table 4 are presented in 1994 dollars.

The reduced tillage continuous cropping system outperformed the other systems on the basis of mean net revenue above total costs. However, the wheat-cotton

Table 2. Average cotton yields on dryland cropping systems at Lubbock, TX, 1988-1994.

Cropping System	1988	1989	1990	1991	1992	1993	1994	Mean	Std. Dev.
					$kg\ ha^{-1}$				
Conventual tillage	263	175	274	178	464	170	110	233	116
Reduced tillage	413	243	271	235	503	221	197	298	115
No-till	343	222	302	177	459	212	110	261	116
Terminated wheat-cotton	298	174	0	183	473	91	81	186	158
Sorghum-cotton reduced	317	263	353	357	512	412	169	340	109
Wheat-cotton reduced	542	637	428	372	576	558	342	494	112

Table 3. Monthly rainfall at Lubbock, Texas, 1988-1994.

	1988	1989	1990	1991	1992	1993	1994	75 year average
					mm			
Jan	8	11	12	30	34	26	9	13
Feb	11	26	44	11	51	10	4	17
Mar	6	17	15	2	35	9	5	22
Apr	36	7	34	0	32	29	79	31
May	58	10	21	45	133	52	97	68
Jun	40	125	5	103	112	96	7	67
Jul	85	8	148	59	43	21	53	56
Aug	11	86	38	53	40	45	2	52
Sep	63	89	27	147	18	6	30	63
Oct	3	0	53	9	0	12	18	50
Nov	6	0	32	29	37	8	19	16
Dec	13	6	10	65	35	8	4	17
Total	340	385	439	552	569	324	327	471
Percent of 75 yr. Mean	72	82	93	117	121	69	69	

National Weather Service, Lubbock, TX.

Table 4. Net revenues above total costs in 1994 prices for dryland cotton systems at Lubbock, TX.

Cropping System	1988	1989	1990	1991	1992	1993	1994	Mean	Std. Dev.
					$\$\ ha^{-1}$				
Conventional tillage	40.88	38.14	63.30	-36.37	251.72	-48.51	-68.32	40.21	104.03
Reduced tillage	202.82	157.13	133.96	34.92	281.38	26.72	69.98	123.61	106.45
No-till	101.81	106.79	103.05	-25.46	180.11	1.41	-50.22	63.91	77.57
Terminated wheat-cotton	72.15	32.80	-161.20	-38.56	192.41	-114.61	-114.44	-9.05	116.25
Sorghum-cotton reduced	78.16	45.00	64.40	56.38	249.55	61.17	-74.10	74.95	80.13
Wheat-cotton reduced	171.55	245.24	77.65	43.65	92.95	142.38	83.98	115.35	75.98

rotation showed a comparable value. The net revenue of these two systems far exceeded those of the remaining four. The systems ranked according to net revenue above total cost in the following order: (1) Reduced tillage continuous cotton; (2) Wheat-cotton reduced tillage; (3) Sorghum-cotton reduced tillage; (4) No-till continuous cotton; (5) Conventional tillage continuous cotton; and (6) Terminated wheat-cotton.

The cropping systems were next ranked using SDRF to determine if the order would change from that found using average net revenues when the standard deviations of those net revenues are considered. Likewise, the SDRF provides insight in determining if the ordered systems might change given alternative levels of producer risk preference represented by the absolute risk aversion coefficient.

The results from the SDRF are found in Table 5. A "1" to the right of any pair of cropping systems indicates that the first cropping system dominated the second. A "-1" to the right of any pair indicates that the second system dominated the first. For example, a "-1" is found to the right of the first pair of systems, CONVTILL-REDTILL, indicating that REDTILL distribution of net revenues dominated CONVTILL distribution of net revenues. Complete examination of the results in

Table 5. Results from SDRF applied to dryland cropping systems.

Dryland cropping systems†			
CONVTILL-REDTILL	-1‡	TWC-CONVTILL	-1
CONVTILL-NOTILL	-1	TWC-REDTILL	-1
CONVTILL-TWC	1§	TWC-NOTILL	-1
CONVTILL-SORGCOT	-1	TWC-SORGCOT	-1
CONVTILL-WHEATCOT	-1	TWC-WHEATCOT	-1
REDTILL-CONVTILL	1	SORGCOT-CONVTILL	1
REDTILL-NOTILL	1	SORGCOT-REDTILL	-1
REDTILL-TWC	1	SORGCOT-NOTILL	1
REDTILL-SORGCOT	1	SORGCOT-TWC	1
REDTILL-WHEATCOT	1	SORGCOT-WHEATCOT	-1
NOTILL-CONVTILL	1	WHEATCOT-CONVTILL	1
NOTILL-REDTILL	-1	WHEATCOT-REDTILL	-1
NOTILL-TWC	1	WHEATCOT-NOTILL	1
NOTILL-SORGCOT	-1	WHEATCOT-TWC	1
NOTILL-WHEATCOT	-1	WHEATCOT-SORGCOT	1

†CONVTILL-Conventional tillage cotton; REDTILL-Reduced tillage cotton; NOTILL-No-till cotton; TWC-Terminated wheat-cotton; SORGCOT-Conservation tillage sorghum-cotton; and WHEATCOT-Conservation tillage wheat-cotton.
‡Second cropping sytem dominated the first.
§First cropping system dominated the second.

Table 5 indicate that reduced tillage dominated all other systems. The overall ranking implied by the results in the table are: (1) Reduced tillage continuous cotton; (2) Wheat-cotton reduced tillage; (3) Sorghum-cotton reduced tillage; (4) No-till continuous cotton; (5) Conventional tillage continuous cotton; and (6) Terminated wheat-cotton.

Upon comparison of the ranking of systems using SDRF to the ranking using average net revenues, the two techniques concluded the same order of systems. However, when the distributions under consideration are more similar, the two techniques often confirm different rankings. In this case, the results from the SDRF are preferred to the results from the average net revenue ranking because the SDRF accounts not only for the average net revenues of the systems, but also for the variability of the net revenues. The cumulative distribution functions for the distributions of returns relative to each cropping system are shown in Fig. 1.

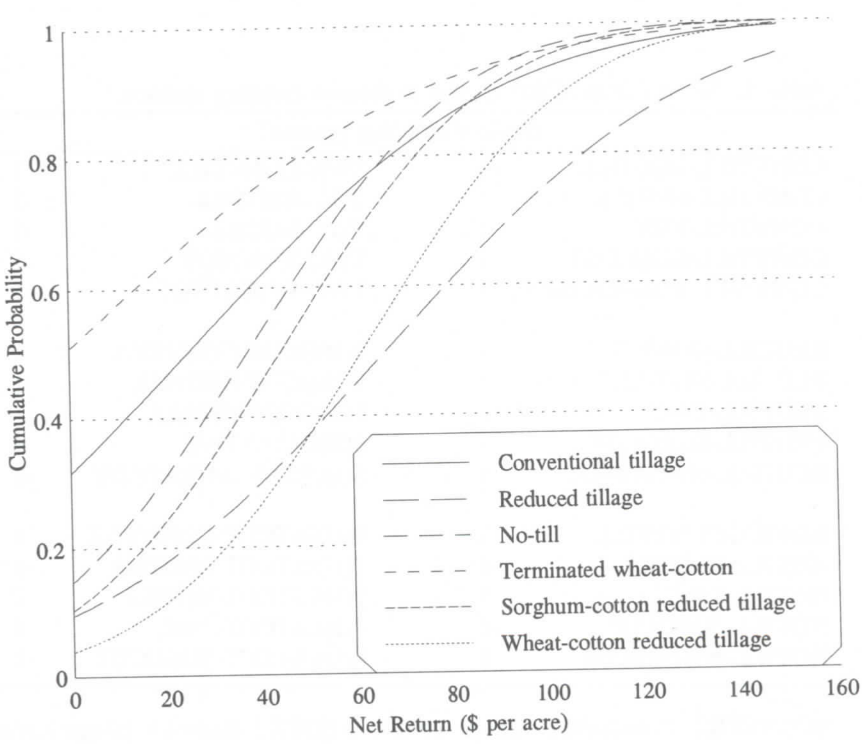

Figure 1. Cumulative distribution functions of cropping system returns.

CONCLUSION

The stochastic dominance with respect to a function analysis of six dryland cotton cropping systems revealed that four of the five conservation tillage systems are superior to the conventional tillage system for all likely producer risk preference levels. These four conservation systems displayed increased stability and profitability over the conventional tillage system, and, hence, are workable options that producers should consider. Conservation tillage systems in dryland cotton production may be better suited to producer risk preferences than conventional practices. Although conservation systems are being used by increasing numbers of farmers, many producers are reluctant to change from conventional practices.

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