ECONOMICS OF IRRIGATED COTTON-GRAIN SORGHUM ROTATIONS IN THE SOUTHERN HIGH PLAINS OF TEXAS

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ABSTRACT

Cotton-grain sorghum rotations in the Southern High Plains of Texas were evaluated using stochastic dominance analysis techniques. The Standardized Performance Analysis program was used to evaluate the profitability of cotton and grain sorghum production using farm level data. Analysis of cotton yields in a cotton-grain sorghum rotation indicated an increase of 190.6 and 159.6 kg ha^{-1} following grain sorghum one and two years, respectively. The rotational effects on cotton yields from grain sorghum had a significant impact on increased cotton profits. All rotational strategies evaluated were preferred to continuous cotton for all levels of risk aversion evaluated in the study.

Key Words: stochastic dominance, Standardized Performance Analysis, crop rotations, irrigation

INTRODUCTION

Grain sorghum has historically been a major field crop in the Southern High Plains (SHP) of Texas. However, total grain sorghum acreage in Texas has steadily decreased since the late 1970s and stabilized at historical lows in the 1990s. This decrease in grain sorghum acreage could possibly be attributed to a reduction of the relative profitability of grain sorghum as compared to other crops. In 2002, grain sorghum represented approximately 13.1% of the total acreage of all Texas field crops but only accounted for approximately 6.5% of the total value of production of all Texas field crops [9]. This reduction of relative profitability may have led producers to plant crops of higher value, thus contributing to the overall decrease in grain sorghum production. Crop budgets for 2002 developed by the Texas Cooperative Extension Service for Extension Districts 1 and 2 (Texas High Plains Region) estimated returns above variable costs of production of \$16.23 and \$-67.90 ha^{-1} (\$6.57 and \$-27.48 ac^{-1}) for sprinkler irrigated cotton on sandy soils and sprinkler irrigated grain sorghum on sandy soils, respectively [10].

There is evidence that crop rotation systems may have a positive impact on soil fertility. Bagayoko, Mason, and Sabata [1] state that “Rotation plays an important role in the maintenance of soil fertility, improvement of soil physical properties, and control of soil erosion” (p. 862). Brodovsky, Trostle, and Segarra [2] reported results for cotton yields in cotton-grain sorghum rotations versus continuous cotton for dryland conditions and two irrigation levels at Halfway, TX for 2001 and 2002. For 2001 there was no significant difference in cotton yields between dryland and irrigated cropping systems. However, in 2002 cotton yields in the cotton-grain sorghum rotation one year following grain sorghum under dryland conditions; and cotton yields one year and two years following grain sorghum under the lower level of irrigation were significantly higher than continuous cotton. Cotton yields in the cotton-grain sorghum rotations under the higher level of irrigation were higher than continuous cotton but not significantly different. Keeling et al. [5] reported that cotton yields in conservation till rotations, including a cotton-grain sorghum rotation, were significantly higher for irrigated cotton production at Lubbock, TX and dryland cotton production at Halfway, TX.

Additionally, there is evidence that grain sorghum can increase farm net returns and yields under a rotational system with cotton. A study by Keeling, Henniger, and Logan [4] for irrigated crop rotations in the SHP for 1989-90 found that a cotton-grain sorghum conservation tillage rotation produced net returns above variable costs of \$638 ha^{-1} (\$258 ac^{-1}) compared to \$504, \$571 and \$613 ha^{-1} (\$204, \$231 and \$248 ac^{-1}) for continuous cotton under conventional tillage, reduced tillage, and no-tillage, respectively.

Farm level information regarding the profitability of grain sorghum produced within crop rotation systems would benefit producers making decisions regarding their cropping systems. The primary objective of this study was to evaluate the profitability of various irrigated grain sorghum and cotton rotation strategies in the SHP of Texas. There is evidence that grain sorghum has the potential to increase the productivity of other crops produced on a rotational basis. However, producers may recognize grain sorghum as less profitable, and fail to realize the resulting higher yields and additional value received by other crops in a rotation. If grain sorghum production is to be sustainable in Texas, producers need information detailing the effects and benefits in overall profitability and production costs resulting from using grain sorghum in crop rotations. Without this information, grain sorghum is likely to continue to be considered an inferior crop among producers and fail to be included in crop rotations in Texas.

METHODS AND MATERIALS

The Standardized Performance Analysis – Multiple Enterprise (SPA-ME) program is an analytical tool that utilizes whole farm financial statements to examine true enterprise performance [6]. The SPA-ME program allows for the allocation of revenues and expenses within the farm financial statements to determination enterprise and sub-enterprise (a specific enterprise on a specific farm or field) cost of production and profitability. The SPA-ME program has been utilized in an ongoing project at Texas Tech University to analyze multiple enterprise farming operations in the SHP of Texas since 1995. Individual farm level analyses of enterprise and sub-enterprise results from this project have been compiled in a database which allows for the aggregation of results across producers and time within the SHP region.

Data

The data utilized in this study was collected from four cotton-grain sorghum producers in the SHP from 1996 to 2000. The data collection process involved obtaining data from each producer which included crop production, marketing, and financial information that was used to complete individual analyses of crop enterprises within their farming operations for each year of the study period using the SPA-ME program. Field maps were obtained from each producer to identify cropping patterns and crop rotations by field for each year of the analysis. A total of 78 irrigated and dryland sub-enterprise observations from the four cotton-grain sorghum producers were included in this study, with all observations being on a crop share basis and representing sub-enterprise level data.

Yield Model

The SPA-ME computer program and SPA database were useful in generating specific enterprise and sub-enterprise cost and profitability results for grain sorghum and cotton as primary crops within a farming operation. However, these methods were not sufficient to analyze the potential affect of grain sorghum on cotton yields and profitability in various cotton-grain sorghum rotations. In order to address rotation strategies, a regression model was utilized to estimate the impact of grain sorghum on cotton yields in a rotation in the SHP. The cotton yield response function used was expressed as:

$$YLD = f(PROD, DC, YR, ICAFS_1, ICAFS_2) \qquad (1)$$

Where YLD is cotton yield in kg ha^{-1}, PROD is a set of four binary variables to reflect different levels of management across the four cotton-grain sorghum producers, DC is a binary variable distinguishing between irrigated and dryland cotton, YR is a set of four binary variables reflecting differences in growing seasons between 1997, 1998, 1999 and 2000, $ICAFS_1$ is an index measuring cotton following sorghum one year (CFS_1) as a percentage of total cotton acres, and $ICAFS_2$ is an index measuring cotton following sorghum two years (CFS_2) as a percentage of total cotton acres. That is, cotton yield ha^{-1} is some function of the level of management, irrigated or dryland cotton, growing season, and cotton acres following grain sorghum one and two years in the rotation as a percentage of total cotton acres.

The indices ($ICAFS_1$ and $ICAFS_2$) were developed to capture and differentiate the effect of grain sorghum on cotton yields one and two years following grain sorghum in the rotation, where the $ICASF_1$ ($ICASF_2$) index is calculated as the cotton acres in each field following grain sorghum one (two) year(s) as a percentage of total cotton acres in that field. In other words, if all cotton acres in the field were following grain sorghum one year in the rotation, the $ICASF_1$ index would have a value of one. Suppose a field had a total of 100 hectares of cotton with 20 and 40 hectares following grain sorghum one and two years, respectively, then the index would be 0.2 and 0.4 for $ICASF_1$ and $ICASF_2$, respectively. For continuous cotton, the $ICASF_1$ and $ICASF_2$ indices would both have a value of zero. Due to data limitations this study assumes that there was no positive impact on cotton yields following grain sorghum three years in a rotation, therefore; this study treats cotton three years following grain sorghum the same as continuous cotton.

Models

In evaluating the profitability of irrigated cotton-grain sorghum rotations in the SHP, two variations of models were developed. The first set of models (mean models) evaluated the impact of the rotation strategy at mean levels with respect to yields, prices, government payments, and production costs. The second set of models (stochastic simulation models) was developed to account for the variability in yields, prices, and production costs.

Mean Models

A total of five models were set up to evaluate the following rotation strategies for irrigated cotton-grain sorghum operations: (1) 1/3 grain sorghum - 2/3 cotton (Rotation A), (2) 1/4 grain sorghum - 3/4 cotton (Rotation B), (3) 1/5 grain sorghum - 4/5 cotton (Rotation C), (4) 1/10 grain sorghum - 9/10 cotton (Rotation D), and (5) continuous cotton (Rotation E). Yields for cotton following grain sorghum one year (CFS_1), cotton following grain sorghum two years (CFS_2), and continuous cotton were estimated from the results of the yield model specified in Equation 1. Average government payments and production costs ha^{-1}; and cotton lint prices kg^{-1} for irrigated cotton were obtained from the SPA database for the producers included in this study. However, irrigated grain sorghum yields, government payments, production costs, and grain sorghum prices were obtained from modified SPA database results for producers included in this study. The grain sorghum data was modified to minimize the impacts of an individual producer that accounted for a large percentage of the irrigated grain sorghum observations and dominated results with above average yields and costs. The modification process involved using the SPA database to generate the per hectare average grain sorghum yield, government payments, production costs, and price received for each individual grain sorghum producer. The results for each individual grain sorghum producer were then weighted based on the following equation:

$$W = C_j / TCO, \qquad (2)$$

where W, C_j, and TCO represent the weighting factor, irrigated cotton observations for producer j, and total irrigated cotton observations across all producers, respectively. The weighted average was then used to determine the grain sorghum yield, government payments, production costs, and prices utilized in the models. This modification was necessary to utilize yields and production costs relative to grain sorghum and cotton that minimized variations in production costs and yields resulting from different levels of management, soil type, and growing conditions.

The mean models for each rotation strategy (including continuous cotton) were set up on a per hectare basis. The appropriate crop yields were calculated and multiplied by the price to determine the primary product income for each component of the rotation (grain sorghum, CFS_1, CFS_2, and continuous cotton). The primary product income combined with the government payments for grain sorghum or cotton determined the total revenue for each component of the rotation. The total revenue was then matched with the appropriate costs (cash operating expenses and overhead costs) to determine the net income for each component of the rotation. Finally, the net income from each component was weighted according to the selected rotation strategy to determine the per hectare net income for the entire rotation. Upon completion of the mean models, results from these models were evaluated to determine the rotation strategy that produced the highest net income for irrigated operations.

Stochastic Simulation Models

The stochastic simulation models were generated and analyzed using SIMETAR, a risk analysis software add-in for Microsoft Excel [7]. A total of 500 simulations were generated to evaluate the specified irrigated rotation strategies. The stochastic models were designed to account for the variability associated with yields, prices, and production costs. The means of prices, cash operating expenses, overhead expenses, and yields were derived in the same manner and are equivalent to the mean levels utilized in the mean models. The standard deviations were calculated in the SPA database for those producers included in the study. However, the SPA database does not distinguish between CFS_1, CFS_2, and continuous cotton, therefore; the standard deviation provided by the SPA database is for all cotton observations without any considerations of rotation strategies. In an effort to derive the appropriate standard deviation for CFS_1, CFS_2, and continuous cotton yields (given they were calculated from the yield equation), the standard deviation across all cotton yields was calculated as a percentage of the mean for all cotton yields. This percentage factor was then multiplied by the appropriate CFS_1, CFS_2, and continuous cotton mean yields (calculated from the yield equation) to obtain an approximation of the standard deviations that accounted for CFS_1, CFS_2, and continuous cotton. All stochastic variables in the stochastic simulation models were truncated by their absolute minimums and maximums within the dataset for simulation purposes. Since government payments were decoupled from production, they were not assumed to be stochastic.

Upon completion of the stochastic simulation models, stochastic dominance (STODOM) analysis was utilized to rank the irrigated cropping rotation strategies. STODOM is a mathematically precise numerical criterion to rank actions or choices for classes of decision makers defined by specified lower and upper bounds of their absolute risk aversion coefficient (ARAC). The ARAC is defined as the -U”(x) divided by U’(x), where U represents a von Neumann-Morgenstern utility function [8, 3, 7]. Hence, a positive ARAC implies a concave utility function resulting in a risk adverse decision maker. Conversely, a negative ARAC implies a convex utility function resulting in a risk loving decision maker. The specification of lower and upper bounds places constraints on the range of risk attitudes entering the STODOM analysis [3]. The advantages of STODOM is that it utilizes all simulated observations and provides an indication into the confidence a decision maker has regarding the ranking of the alternative cropping rotation strategies [7]. Furthermore, the results from STODOM should be preferred to the average results under the mean models, which do not internalize any considerations for risk preferences.

RESULTS AND DISCUSSION

Yield Model

Several model specifications were estimated using ordinary least squares estimation procedures, with various statistical tests being used to select the optimal model. In all of the regression models estimated, there were a total of 78 farm level sub-enterprise observations representing four producers within the SHP for the years 1998 to 2000 (two years were lost due to lags for CFS_1 and CFS_2).

The initial model framework specified cotton yields per hectare as a function of: (1) a set of binary variables representing different producers; (2) a set of binary variables representing crop year, with 1998 the baseline year; (3) an index specifying the crop area of cotton following grain sorghum one year (CFS_1); and (4) an index specifying crop area of cotton following grain sorghum two years (CFS_2) in a rotation.

Initial estimates of the yield model, determined that there were no statistical differences for the years 1997 and 1999 compared to the baseline. There was also no statistical difference between three of the four producers. Statistical tests using various specifications of squared and inverse terms, determined that the relationship between cotton yields per hectare and the indices was linear. Slope shifters were included in the model to test if there was a statistical difference in the slope of the indices with respect to irrigated and dryland cotton. All slope shifters, however, were determined to be statistically insignificant at the ninety-five percent level of statistical certainty.

After evaluating several regression model specifications and adjusting the model as dictated by statistical tests, the following equation was estimated:

$$YLD = 362.3 + 712.8*PROD3 - 140.1*DC + 86.59*Y2000 + 190.64*ICAFS1 + 159.6*ICAFS2 \quad (3)$$

where, YLD, $PROD_3$, DC, Y2000, $ICAFS_1$, and $ICAFS_2$ represent cotton yield in kg ha^{-1}, a binary variable for producer 3, a binary variable for dryland cotton, a binary variable for the year 2000, an index for CFS_1, and an index for CFS_2, respectively. The $ICASF_1$ parameter estimate of 190.6 implies that cotton yields increased by 190.6 kg ha^{-1} (170.2 lb ac^{-1}) on CFS_1 in a rotation. Likewise, the $ICASF_2$ parameter estimate of 159.6 implies that cotton yields increased by 159.6 kg ha^{-1} (142.5 lb ac^{-1}) for CFS_2 in a rotation. The $ICAFS_1$ and $ICAFS_2$ parameter estimates were consistent with what was hypothesized with respect to expected sign.

The estimation results for equation 3 are given Table 1 and indicate that all independent variables were statistically significant at the ninety-five percent level of statistical certainty according to t-tests and p-values. The estimated model had an R-squared of 0.86 and an F-statistic of 89.45 which was statistically significant at the ninety-five percent level of statistical certainty. No evidence of multicollinearity as indicated by the variance inflation factors and condition indices. Results from the Durbin-Watson test statistic and the White test also indicated no evidence of autocorrelation or heteroskedasticity in the model, respectively

Table 1.
Cotton Yield Estimation Model.

Total Observations	78
Degrees of Freedom	72
R-Squared	86.10%
F-Statistic	89.446

Variable	Estimate	Standard Error	t-Value	p-value
Intercept	362.33	24.05	15.06	0.000
Producer 3 Binary Variable	712.78	53.17	13.41	0.000
Dry Cotton Binary Variable	-140.14	38.39	-3.65	0.000
2000 Binary Variable	86.59	35.48	-2.44	0.017
$ICAFS_1$[1]	190.64	55.05	3.46	0.001
$ICAFS_2$[2]	159.60	78.23	2.04	0.045

[1] $ICAFS_1$ is an index of cotton acreage following grain sorghum one year.
[2] $ICAFS_2$ is an index of cotton acreage following grain sorghum two years.

Mean Models

Data from four irrigated producers in the SHP from 1998 to 2000 (78 sub-enterprise observations) was utilized in the mean models to evaluate irrigated cotton-grain sorghum rotations for the following rotation strategies: (1) 1/3 grain sorghum - 2/3 cotton (Rotation A), (2) 1/4 grain sorghum - 3/4 cotton (Rotation B), (3) 1/5 grain sorghum - 4/5 cotton (Rotation C), (4)1/10 grain sorghum - 9/10 cotton (Rotation D), and (5) continuous cotton. Rotation D was included to account for producers who do not follow a rotation strategy, but occasionally plant grain sorghum behind failed cotton.

The data used in the mean models for irrigated grain sorghum; CFS_1, CFS_2, and continuous cotton are provided in Table 2. The per hectare yield, revenues, expenses, and net incomes remained constant for each component (grain sorghum, CFS_1, CFS_2, and continuous cotton) in all of the models. However, the weight applied to each component in calculating the total rotation net income (TRNI) on a per hectare basis varied according to the rotation strategy applied. For example, Rotation A implies that grain sorghum, CFS_1, and CFS_2 each account for one third of the total planted area. Additionally, Rotation C implies that grain sorghum, CFS_1, and CFS_2 each accounts for 1/5 of the total planted area with continuous cotton accounting for 2/5 of the total planted area. [Table 2 about here]

The mean models assumed a crop share yield of 2465 kg ha^{-1} (2201 lb ac^{-1}) and a price of \$0.0823 kg^{-1} (\$0.03732 lb^{-1}) for grain sorghum. This resulted in primary product income of \$203.86 ha^{-1} (\$82.50 ac^{-1}) for grain sorghum observations included in the models. Government payments were \$87.00 ha^{-1} (\$35.21 ac^{-1}) resulting in total revenue of \$290.86 ha^{-1} (\$117.71 ac^{-1}) for irrigated grain sorghum. Total cash operating and overhead expenses were \$372.52 and \$74.38 ha^{-1} (\$150.76 and \$30.10 ac^{-1}), respectively. This resulted in a negative net income of \$-156.04 ha^{-1} (\$-63.15 ac^{-1}) for irrigated grain sorghum within the mean models.

The mean models assumed that all irrigated cotton received or incurred the same cotton lint price, government payments, cash operating expenses, and overhead expenses. Cotton lint price of \$1.2544 kg^{-1} (\$0.5689 lb^{-1}) and government payments of \$137.39 ha^{-1} (\$55.60 ac^{-1}) were used in the model. Cash operating and overhead expenses were specified at \$505.66 and \$82.31 ha^{-1} (\$204.64 and \$33.31 ac^{-1}), respectively, for all cotton observations. Cotton yields for the cotton components of the mean models were estimated using Equation 3. The effects of the year 2000 and producer 3 were weighted back into the intercept to obtain an average irrigated cotton yield for continuous cotton across all producers and years.

These adjustments resulted in an estimated average total cotton yield of 450 kg ha^{-1} (402 lb ac^{-1}) for irrigated continuous cotton in the SHP. This total yield, however, was adjusted to a crop share yield given that the database used in this study was on a crop share basis. Making this adjustment resulted in a continuous cotton crop share yield of 338 kg ha^{-1} (302 lb ac^{-1}) for irrigated production. The yield equation (Equation 3) indicated that cotton yields would increase by 190.6 and 159.6 kg ha^{-1} (170.2 and 142.5 lb ac^{-1}) for CFS_1 and CFS_2, respectively. The estimated total yields for CFS_1 and CFS_2 were 641 kg ha^{-1} (572 lb ac^{-1}) and 611 kg ha^{-1} (546 lb ac^{-1}), respectively. Adjusting these total yields by 75% resulted in crop share yields of 481 and 458 kg ha^{-1} (430 and 409 lb ac^{-1}) for CFS_1 and CFS_2, respectively. Assuming crop share yields and cotton lint price of \$1.2544 kg^{-1} (\$0.5689 lb^{-1}) primary product income was simulated at \$603.57, \$574.36, and \$424.22 ha^{-1} (\$244.26, \$232.44 and \$171.68 ac^{-1}) for CFS_1, CFS_2, and continuous cotton, respectively. This resulted in mean simulated net incomes of \$152.98, \$123.77, and \$-26.37 ha^{-1} (\$61.91, \$50.09 and \$-10.67 ac^{-1}) for CFS_1, CFS_2, and continuous cotton, respectively.

Table 2.
Mean Model Data for Irrigated Crop Rotations on a Crop Share Basis for the SHP. [1]

	Grain Sorghum	CFS_1[2]	CFS_2[3]	Continuous Cotton
	(kg ha^{-1})			
Total Yield	3,698.1	641	611	450
Crop Share Yield	2,465.4	481	458	338
	(\$ ha^{-1})			
Primary Product	203.86	603.57	574.36	424.22
Government Payments	87.00	137.39	137.39	137.39
Total Revenue	290.86	740.95	711.75	561.61
Cash Operating Expenses	372.52	505.66	505.66	505.66
Overhead Expenses	74.38	82.31	82.31	82.31
Total Enterprise Cost [4]	446.91	587.97	587.97	587.97
Net Income	-156.04	152.98	123.77	-26.37

[1] Tenant crop share percentage is assumed 2/3 for irrigated grain sorghum and 3/4 for irrigated cotton.

[2] CFS_1 is cotton following grain sorghum one year.

[3] CFS_2 is cotton following grain sorghum two years.

[4] Total enterprise cost does not include family living withdrawals.

Table 3.
Irrigated Grain Sorghum and Cotton Mean Model Results on a Crop Share Basis. [1]

Rotation	Grain Sorghum	CFS_1[2]	CFS_2[3]	Continuous Cotton	TRNI [4]
	(\$ ha^{-1})				
1/3 Irrigated Grain Sorghum - 2/3 Irrigated Cotton	-52.01	51.00	41.76	0.00	40.75
1/4 Irrigated Grain Sorghum - 3/4 Irrigated Cotton	-39.02	38.25	30.94	-6.60	23.60
1/5 Irrigated Grain Sorghum - 4/5 Irrigated Cotton	-31.21	30.59	24.76	-10.55	13.59
1/10 Irrigated Grain Sorghum - 9/10 Irrigated Cotton	-15.62	15.30	12.38	-18.46	-6.40
Continuous Irrigated Cotton	0.00	0.00	0.00	-26.37	-26.37

[1] Tenant crop share percentage is assumed 2/3 for irrigated grain sorghum and 3/4 for irrigated cotton.
[2] CFS_1 is cotton following grain sorghum one year.
[3] CFS_2 is cotton following grain sorghum two years.
[4] Total Rotation Net Income (TRNI) is weighted per hectare based on the rotation.

Considering the yields, revenues, expenses, and net incomes simulated for the irrigated grain sorghum and cotton components, models were developed to evaluate each of the rotation strategies. A summary of the mean model results for each rotation strategy are provided in Table 3. The results indicated that the TRNI for all rotation strategies was higher when compared to continuous cotton. The results indicated that the highest TRNI was for Rotation A, with a rotation of 1/3 irrigated grain sorghum, CFS_1, and CFS_2. Rotation A resulted in weighted net incomes of \$-52.01, \$51.00, and \$41.76 ha^{-1} (\$-21.05, \$20.64 and \$16.90 ac^{-1}) for grain sorghum, CFS_1, and CFS_2, respectively. Summing the weighted net incomes resulted in a TRNI for Rotation A of \$40.74 ha^{-1} (\$16.49 ac^{-1}) The TRNIs for Rotations B, C, and D were estimated at \$23.60, \$13.59, and \$-6.40 ha^{-1} (\$9.55, \$5.50 and \$-2.59 ac^{-1}), respectively. The mean model indicated negative net returns of \$-26.37 ha^{-1} (\$-10.67 ac^{-1}) for continuous cotton. Hence, all rotation strategies evaluated resulted in higher TRNIs to the producer when compared to continuous cotton. [Table 3 about here]

Stochastic Simulation Models

The mean simulation models provide evidence that producers in the SHP should be willing to consider adopting a cotton-grain sorghum rotation. However, the mean simulation models did not consider risk preferences or take into account the variability associated with prices, yields, and production costs. Therefore, stochastic simulation models were developed to evaluate how the results might change when accounting for variability and considerations of different risk preferences. The stochastic simulation models were also evaluated using the rotation strategies A through E as previously described.

The data used in the stochastic simulation models for irrigated grain sorghum, CFS_1, CFS_2, and continuous cotton are provided in Table 4. Crop yields, prices, variable expenses, and fixed expenses were assumed to be stochastic. The input data shown in Table 4 provides the means, standard deviations, absolute minimums, and absolute maximums associated with the stochastic variables utilized in the simulation models. This input data was used to generate the stochastic variables with the truncated normal function in Microsoft Excel. From this information, models were developed to simulate 500 TRNI observations for each rotation strategy, while accounting for the stochastic nature of yields, prices, and production costs. [Table 4 about here]

Table 4.
Stochastic Simulation Model Input Data.

Variables	Units	Mean	Std. Dev.	Min	Max
PDF [1] for price of cotton	$ kg^{-1}	1.25	0.72	0.86	1.56
PDF for price of grain sorghum	$ kg^{-1}	0.083	0.042	0.061	0.119
PDF for yield of continuous cotton	kg ha^{-1}	338	159.06	262.30	977.16
PDF for yield of cotton following grain sorghum one year	kg ha^{-1}	481	225.95	372.60	1,388.08
PDF for yield of cotton following grain sorghum two years	kg ha^{-1}	458	215.42	355.23	1,323.37
PDF for yield of grain sorghum	kg ha^{-1}	2,465	1,098.22	1,148.65	7,686.43
PDF for total variable costs of cotton	$ ha^{-1}	505.67	236.75	337.44	1,008.51
PDF for total variable costs of grain sorghum	$ ha^{-1}	372.53	154.37	191.38	811.82
PDF for total fixed costs of cotton	$ ha^{-1}	82.31	28.10	59.67	98.77
PDF for total fixed costs of grain sorghum	$ ha^{-1}	74.38	43.51	43.98	92.04

[1] Probability Density Function

Upon completion of the simulated observations, stochastic dominance (STODOM) analysis was used to evaluate each of the rotation strategies. STODOM was utilized to allow comparisons between various levels of risk aversion and risk neutrality. The STODOM analyses were conducted in SIMETAR for twenty alternative levels of risk aversion coefficients. Recall that a positive ARAC implies risk aversion, while a negative ARAC implies risk taking. STODOM analyses were conducted on various ARAC's ranging from -0.05 to 0.05 with the results presented in Table 5. Under an ARAC ranging from -0.05 to -0.045, the preferred crop rotation strategy was to plant continuous cotton (Rotation E) followed by a descending ranking of crop Rotations D, A, B, and C. The STODOM analyses for ARAC's ranging -0.04 to -0.03 also indicated that the preferred crop rotation strategy was to plant continuous cotton (Rotation E). However, the ranking slightly changed compared to the higher levels of risk loving preferences to a descending ranking following continuous cotton of Rotations A, D, B, and C. Under an ARAC of -0.025, the preferred crop rotation strategy was the 1/3 grain sorghum – 2/3 cotton rotation strategy (Rotation A) followed by a descending ranking of Rotations E, D, B, and C. Furthermore, as the ARAC increased from -0.025 towards risk neutrality, the descending ranking of preferred crop rotations changed to a descending ranking of Rotations A, B, C, D, and E. This crop rotation ranking held for ARAC's ranging from -0.01 and 0.05.

Table 5.
Rotation Preference Based on Stochastic Dominance Ranking.

	Absolute Risk Aversion Coefficient (ARAC)[6]												
Ranking	-0.05	-0.045	-0.04	-0.03	-0.025	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
1 (most pref.)	E[2]	E	E	E	A	A	A	A	A	A	A	A	A
2	D[4]	D	A	A	E	B	B	B	B	B	B	B	B
3	A[1]	A	D	D	D	C	C	C	C	C	C	C	C
4	B[2]	B	B	B	B	D	D	D	D	D	D	D	D
5 (least pref.)	C[3]	C	C	C	C	E	E	E	E	E	E	E	E

[1] Rotation A: 1/3 Irrigated Grain Sorghum - 2/3 Irrigated Cotton
[2] Rotation B: 1/4 Irrigated Grain Sorghum - 3/4 Irrigated Cotton
[3] Rotation C: 1/5 Irrigated Grain Sorghum - 4/5 Irrigated Cotton
[4] Rotation D: 1/10 Irrigated Grain Sorghum - 9/10 Irrigated Cotton
[5] Rotation E: Continuous Cotton
[6] A positive ARAC implies risk aversion, while a negative ARAC implies risk taking.

SUMMARY AND CONCLUSIONS

Results of the regression model indicated that cotton yields would be expected to increase by 190.6 and 159.6 kg ha^{-1} (170.2 and 142.5 lb ac^{-1}) following grain sorghum one and two years, respectively, in a rotation. This increase in cotton yields appeared to have a significant impact on increased cotton profits when evaluated by the mean simulation models. Analysis of the mean rotation simulation results provided evidence for the profitability potential of utilizing grain sorghum in rotations with cotton. However, the STODOM results produced starkly different results depending on the assumption made with respect to risk preferences. For risk taking producers, STODOM analysis indicated continuous cotton was preferred followed by different rankings of the remaining rotation strategies depending on their ARAC. However, as a producer approaches risk neutrality, the STODOM analysis indicated that producers should be more willing to adopt cotton-grain sorghum rotations, and specifically Rotation A. Furthermore, all rotation strategies were preferred to continuous cotton for all levels of risk aversion evaluated in this study. While the STODOM results produced more variability than one would desire, these should still be preferred to the mean results for decision making purposes. The advantage of the STODOM analysis is that this approach accounts for differences in risk preferences and variability in yields, prices, and production costs. Furthermore, given a producer’s risk preferences, the STODOM analysis could help identify the optimal rotation strategy given their individual preferences towards risk. It is important to highlight that the crop rotation data used in this analysis was based on four selected irrigated producers in the SHP. Results may vary from producer to producer depending on management strategies, weather conditions, and soil qualities.

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