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Risk Analysis of Tillage and Crop Rotation Alternatives with Winter Wheat

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The economic feasibility of soybeans, grain sorghum, and corn in annual rotation with winter wheat using reduced tillage and no-tillage systems in the Central Great Plains was evaluated, with continuous wheat and grain sorghum also analyzed. Net returns were calculated using simulated yield and price distributions based on historical yields, two historical annual price series, and 2011 costs. Stochastic Efficiency with Respect to a Function was used to determine the preferred strategies under various risk preferences. The no-till wheat-soybean and reduced-till wheat-soybean systems are the first and second most preferred, regardless of the level of risk aversion.

Key Words: corn, crop rotations, grain sorghum, no-tillage, risk analysis, soybeans, wheat

JEL Classifications: Q12, Q15

This study examines the economic feasibility of soybeans, grain sorghum, and corn production in annual rotation with winter wheat using reduced tillage (RT) and no-tillage (NT) systems in the Central Great Plains. Monoculture wheat and grain sorghum are also analyzed. Due to the climatic conditions of south-central Kansas, wheat historically has been and continues to be the predominant crop planted in the area. Approximately 71% of all the harvested dryland crop acres (composed of wheat, sorghum, corn, and soybeans) in a 13 county area of south-central Kansas were wheat acres in 2009 (U.S. Department of Agriculture (USDA) National Agricultural Statistics Services (NASS), 2010). However, this is down from 76% in 2005. Soybeans increased from 4.8% in 2005 to 10.4% in 2009, while corn increased from 3.9% to 5.2%; and grain sorghum declined from 15.4% to 13.5%. Farms in the south-central Kansas Farm Management Association (KFMA) have shown a similar trend from 2005–2010. Dryland soybean acreage has increased from 8.0% to 18.4%; corn has increased from 5.3% to 8.9%; while sorghum has declined from 21.9% to 14.0%; and wheat has declined from 64.8% to 51.4% (KFMA, 2011).

Managers in this area have historically used conventional tillage. The traditional crop choices have been wheat and grain sorghum, since these crops are less sensitive to moisture stress than corn and soybeans. However, the demand for soybeans and corn has greatly increased with the increased production of renewable fuels, particularly ethanol. This increase in demand has left producers trying to optimize the balance of wheat acres and row crops (Claassen, 2009).

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Improved water-use efficiency from adoption of no-till and reduced tillage systems has allowed producers to rotate summer crops with wheat in environments that did not consistently support summer row-crop production with conventional tillage (Farahani et al., 1998). The use of these rotations has also reduced weed density, and enabled producers to use alternative weed management strategies that improve the effectiveness of herbicides used, and minimize herbicide resistance (Anderson, 2004).

Previous studies in this region have examined the economic feasibility of conservation tillage and alternative dryland rotations. However, these have mostly been limited to wheat and sorghum. Epplin et al. (1982, 1983) examined tillage systems for wheat in the Great Plains and concluded that some of the conservation systems had net returns that were competitive with those of conventional tillage. Williams (1988) analyzed dryland tillage systems for wheat and grain sorghum in western Kansas, concluding that risk-averse managers would prefer reduced tillage systems, given the reduced costs and increased yields for both crops.

Risk analysis of crop rotations and tillage systems by Williams, Roth, and Claassen (2000) in west-central Kansas found that a rotation of reduced-tillage grain sorghum and no-till wheat was preferred by moderately risk-averse producers, while more strongly risk-averse producers preferred a rotation of reduced-tillage grain sorghum and reduced-tillage wheat. Rotations of the two crops were economically advantageous compared with continuous cropping. Profitability increased with the use of crop rotations due to the added benefits of weed growth disruption and a reduction in the severity of plant diseases (Anderson, 2008). This study also found reduced cost of weed management was a major factor of improved net returns, as well as increased land productivity.

Stochastic Efficiency with Respect to a Function (SERF) analysis, which is used in the study, has previously been used to evaluate crop production systems. Barham et al. (2011) used SERF analysis to rank alternative scenarios involving varying irrigation levels, crop insurance, and the use or non-use of put options over a range of relative risk aversion for a representative cotton farm in Texas. Bryant et al. (2008) used data from three years of field studies at two locations in Arkansas to evaluate returns to four cottonseed technology options using SERF with a negative exponential utility function. Hignight, Watkins, and Anders (2010) evaluated five rice-based cropping systems in Arkansas (continuous rice, rice-soybean, rice-corn, rice-wheat, and rice-wheat-soybean-wheat) using SERF analysis. They found that producers preferred a rice-soybean rotation, regardless of tillage system, and that no-tillage generally was preferred to conventional tillage. Pendell et al. (2007) also used the technique to examine net return distributions from tillage and fertilizer combinations designed to enhance soil carbon sequestration. These studies used net return distributions based on empirical data.

The goal of this analysis is to determine which tillage systems and row crops rotated with winter wheat are preferred under varying degrees of risk preference for producers in the central Great Plains. Corn, soybeans, and grain sorghum were grown in annual rotation with winter wheat under no-till and reduced-tillage. Systems examined also included no-till and reduced-till continuous wheat and continuous grain sorghum.

Data and Methods

Overview

Distributions of net returns to land and management were calculated using simulated yield and price distributions based on actual historical yields, annual marketing year price series, and 2011 input costs. The following systems were examined in the analysis:

1. RTWS Reduced-till Wheat-Soybean
2. NTWS No-till Wheat-Soybean
3. RTGG Reduced-till Continuous Grain Sorghum
4. NTGG No-till Continuous Grain Sorghum
5. RTWW Reduced-till Continuous Wheat
6. NTWW No-till Continuous Wheat
7. RTWG Reduced-till Wheat-Grain Sorghum
8. NTWG No-till Wheat-Grain Sorghum
9. RTWC Reduced-till Wheat-Corn
10. NTWC No-till Wheat-Corn.

SERF was used to rank the various systems using utility-weighted certainty equivalents for various degrees of risk aversion. The certainty equivalents were used to calculate risk premiums at each risk aversion level.

Study Area and Field Operations

Net returns from enterprise budgets were developed for the 10 cropping systems in the study. Yield and input data for the budgets were collected from the Harvey County Experiment Field in south-central Kansas from 1997–2006. The experiment was arranged in a randomized complete block design with four replications. The plots were 30′ × 50′. Each phase of all cropping systems was present every year so that all crops were grown and harvested in all 10 years of the study. Harvey County is located in the Central Great Plains Winter Wheat and Range Land Resource Region. The soil series for the experiment location is classified as a Ladysmith silty-clay loam. It is one of two soil associations in the region. These soils typically occur in the Central Loess Plains and are usually found where the land is level to gently sloping with slopes ranging from 0 to 3% (USDA Natural Resources Conservation Service, 2010). The average annual precipitation for four counties in the experiment field area over the 30-year period, 1980 through 2009, was 31.2 in. per year and was 32.1 in. per year for the experiment study period 1997 through 2006 (Kansas State Research and Extension, 2012). Precipitation at the experiment field for the 30-year period was 33.0 in. and 32.8 in. per year for the 10-year study period.

When wheat is rotated with a row crop, winter wheat is planted in mid-October and harvested the following June. The row crop is then planted the following spring and harvested in early October. Wheat planting then follows row crop harvest. Winter wheat was planted with a no-till drill with 7.5-in. row spacing in both reduced till and no-till systems. A no-till planter with double-disk openers on 30-in. centers was used to plant corn, sorghum, and soybeans in both reduced till and no-till systems. Crop residue was evenly distributed at harvest and planting into the residue occurred in the no-till systems. Glyphosate-ready corn and soybean seed was used. For the reduced tillage systems, weeds were controlled using either one or a combination of the following implements: field cultivator, V-blade, chisel, disk, roller harrow, and two customized implements (sweep and mulch treader) plus herbicides. In the no-till systems, weed control was accomplished solely with herbicides. Table 1

Table 1. Annual Frequency of Field Operations[a]

System[b]	RTWS	NTWS	RTGG	NTGG	RTWW	NTWW	RTWG	NTWG	RTWC	NTWC
Tillage operations										
Chisel			1.00		1.00					
Disk					1.00					
Roller harrow					0.25					
Field cultivate					0.25					
V-blade	0.75						0.75		0.75	
Sweep treader	3.75		1.25		1.50		3.75		3.00	
Mulch treader			0.75		0.25				0.50	
Total tillage operations	4.50	0.00	3.00	0.00	4.25	0.00	4.50	0.00	4.25	0.00
Herbicide applications	2.25	5.75	1.00	2.25	0.50	3.25	1.75	5.75	2.00	4.50
Total	6.75	5.75	4.00	2.25	4.75	3.25	6.25	5.75	6.25	4.50

[a] Numbers indicate the average number of field operations used per year excluding planting, fertilizing, and harvesting, which were the same for each system.

[b] WS, Wheat-Soybean; GG, Continuous Grain Sorghum; WW, Continuous Wheat; WG, Wheat-Grain Sorghum; WC, Wheat-Corn; RT, reduced-till; NT, no-till.

summarizes the number of field operations, excluding planting, fertilizing, and harvesting for each system. All field operation costs are calculated using custom rates (Dhuyvetter, 2011).

Nitrogen (N) and phosphorus sources were the same for all crops. Fertilizer rates were kept constant across rotations. Wheat received 107 lbs per acre of N from urea before planting in the fall and 74 lbs per acre of Di-ammonium phosphate (DAP) at planting. Soybeans received 20 lbs per acre of DAP at planting. Grain sorghum received 102 lbs per acre of N from urea and 80 lbs per acre of DAP. Corn also received 107 lbs per acre of N from urea and 80 lbs per acre of DAP at planting.

Due to a computer failure during the experiment, the corn yields for the year 2000 in the wheat-corn rotation were lost. To replace the year 2000 corn yields the following procedure was used. Two regression equations were estimated with corn yield as a function of the grain sorghum yield from the wheat-grain sorghum rotation. In the first equation, the RT corn yield (the dependent variable) from years 1997–1999 and 2001–2006 was regressed on the RT grain sorghum yield (the independent variable) from years 1997–1999 and 2001–2006. In the second equation, the NT corn yield from years 1997–1999 and 2001–2006 was regressed on the NT grain sorghum yield from years 1997–1999 and 2001–2006. The coefficients for each equation were significant ($\alpha = 0.05$) and the R-Squares were 0.73 and 0.82, respectively. The RT and NT grain sorghum yield from the year 2000 was entered in the first and second regression equations to estimate the RT and NT corn yield for the year 2000.

Simulated Net Returns

Simulation and Econometrics to Analyze Risk (SIMETAR©) developed by Richardson, Schumann and Feldman (2008) was used to develop multivariate empirical simulated yield and price distributions for calculating distributions of net returns to land and management using 2011 costs. Net return distributions were constructed using Equation 1.

$$(1) \quad NR_{ijk} = \Sigma_{j=1}^{2}\left(Y_{ijk} \times EP_{ij} - C_{jk} - HC_{ijk}\right)/2$$

where

NR_{ijk} = net return to land and management ($/acre) for observation i of crop j for crop production system k,

i = observation, $i = 1 - 2000$,

j = crop, $j = 1 - 2$,

k = crop production system k, $k = 1 - 10$,

Y_{ijk} = simulated yield (bu/acre) for observation i of crop j for crop production system k,

EP_{ij} = simulated price ($/bu) for observation i for crop j,

C_{jk} = preharvest production costs ($/acre) for crop j in production system k,

HC_{ijk} = harvest cost ($/acre) for yield observation i for crop j in production system k.

Crop yields and prices in the model are stochastic, while all costs except harvest costs, which vary with yield, are pre-determined and static, based on 2011 costs. A simulated correlated multivariable empirical yield distribution derived from actual historical yields was multiplied by a simulated multivariate empirical price distribution derived from actual historical prices to calculate gross returns for each cropping system. Current year production and harvest costs were then subtracted from gross returns to obtain the net return. It was assumed that each crop in rotation was grown on one acre, so the net return was divided by two and reported as $/acre of a rotation.

Empirical distributions were specified using the yield and price data following Richardson, Klose, and Gray (2000), because too few observations existed to estimate parameters for another distribution (e.g., truncated normal distribution). The price and yield distributions were generated in the following manner: a cumulative probability distribution function (CDF) using the 10 years of yield data with the probability ranging from 0.0 to 1.0 was formed by ordering the data and assigning a cumulative probability for each observation. The same process was repeated using annual marketing year prices from 2006 through 2010 and 1997 through 2006. These price data sets were used to compare results under two quite different price regimes. The 2006–2010 series captures the variability and increase in crop prices that has occurred after 2005. Irwin and Good (2011) contend that there has been a structural shift upward in prices beginning in 2007. We used a series beginning in 2006 because south-central Kansas prices were higher in every month of 2006 than the corresponding months during 2005 for wheat and corn, but the 2006 values for sorghum were equal to or greater than the 2005 values (USDA NASS, 2011a). Soybean prices were lower in most months of 2006 than 2005. A summary of the annual price distribution characteristics is reported in Table 2. Prices were not allowed to fall below the 2011 commodity program loan rate for each commodity. Commodity program payments were not considered because they do not impact the managers' cropping decision.

Each yield or price observation was assumed to have an equal probability of occurring. A simulated distribution of 2,000 observations was generated by drawing 2,000 values from a uniform standard deviate ranging in value from zero to one. The corresponding price or yield assigned to the distribution was from the cumulative probability represented by the uniform standard deviate value. The price was found by interpolation if the value from the uniform standard deviate fell between the cumulative probabilities assigned the original data values (Pendell et al., 2007). A multivariate empirical distribution has been shown to correlate random yields appropriately, based on their historical correlation (Richardson, Klose, and Gray, 2000). The multivariate empirical distribution is a closed-form distribution, which eliminates the possibility of simulated values exceeding values observed in history (Ribera, Hons, and Richardson, 2004).

Table 2. Simulated Annual Commodity Price Distribution Characteristics ($/bu)

		Corn	Wheat	Soybean	Sorghum
2006 to 2010	Mean	$4.01	$5.48	$9.45	$3.74
	SD	$0.69	$0.82	$1.72	$0.72
	CV	0.17	0.15	0.18	0.19
	Min	$3.08	$4.56	$6.37	$3.06
	Max	$5.25	$6.94	$12.00	$5.07
1997 to 2006	Mean	$2.27	$3.26	$5.68	$2.19
	SD	$0.33	$0.44	$0.81	$0.40
	CV	0.15	0.13	0.14	0.18
	Min	$1.95	$2.94	$5.00	$1.95
	Max	$3.08	$4.56	$7.68	$3.37

CV, coefficient of variation.

Correlations between all yield and price series were included in the multivariate empirical simulated data. Yield correlations for each yield series with each other series ranged from −0.10 to 0.99. The annual price data used were positively correlated, with price correlations ranging from 0.37 to 0.94. Prices correlated with yields ranged from −0.40 to 0.71. T-tests and F-tests were used to test for significant differences between the simulated data and the actual data. The statistical tests indicated the differences between the mean and variances of the experimental yield data and historical prices, and the simulated yields and prices were not statistically different.

Stochastic Efficiency with Respect to a Function

Stochastic efficiency with respect to a function orders a set of risky alternatives in terms of certainty equivalents (CEs) and risk premiums derived from the difference in CEs for a specified risk preference (Hardaker et al., 2004). The CE value is the amount of certain payoff an individual requires to be indifferent between that payoff and the payoff of the risky alternative. The difference between CE values at a specific risk aversion level is known as the risk premium and represents the minimum certain amount that has to be paid to an individual for the individual to be willing to switch from the less risky alternative to the more risky alternative (Hardaker et al., 2004). SERF orders preferred alternatives in terms of CEs as the degree of risk aversion increases. Strategies with higher CEs are preferred to those with lower CEs. The CE of a risky strategy is the amount of money at which the decision-maker is indifferent between the certain (generally lower) dollar value and the expected value of the risky strategy. For a risk-averse decision-maker, the estimated CE is typically less than the expected value of the risky strategy.

The calculation of the CE depends on the utility function specified. Given a negative exponential utility function, which is used in this analysis, a specific absolute risk aversion coefficient (ARAC) defined by Pratt (1964) as, $r_a(w) = -u''(w)/u'(w)$, which represents the ratio of the second and first derivatives of the decision-maker's utility function, $u(w)$, is used to derive CEs.

A negative exponential utility function used in the SERF analysis conforms to the hypothesis that managers prefer less risk to more given the same expected return. This functional form assumes managers have constant absolute risk aversion. Under this assumption, managers view a risky strategy for a specific level of risk aversion the same without regard for their level of wealth. Babcock, Choi, and Feinerman (1993) note that this functional form is often used to analyze farmers' decisions under risk. For additional justification for this functional form, refer to Schumann et al. (2004). Their work demonstrates that negative exponential function can be used as a reasonable approximation of risk-averting behavior.

The simulated net return data outcomes from each crop production system were sorted into CDFs, which were used in the SERF analysis. Once the strategies were ranked using the CE results, a utility-weighted risk premium was calculated using Equation 2 (Hardaker et al., 2004). This was accomplished by subtracting the CE of a less preferred strategy (L) from the preferred strategy (P).

$$(2) \qquad RP_{P,L,ra} = CE_{P,r_a(w)} - CE_{L,r_a(w)}$$

The risk premium for a risk-averse decision-maker reflects the minimum amount (\$/acre) that a decision-maker has to be paid to justify a switch from the preferred strategy (P) to a less-preferred strategy (L) under a specific risk-aversion coefficient ($r_a(w)$). These risk premiums and the resulting rankings are reported in graphical form for a range of ARACs from risk-neutral to very risk-averse. An ARAC equal to zero means the decision-maker is risk-neutral. As the ARAC increases from zero, so does the decision-maker's risk aversion, or desire to avoid risk. Anderson and Dillon (1992) proposed a relative risk aversion definition of 0.0 as risk neutral and 4.0 as extremely risk averse. Thus, as suggested by Hardaker et al. (2004), the upper range of ARAC for use with a negative exponential utility function is calculated by dividing 4.0 by an appropriate level of wealth. In this case, the measure of wealth is the average per acre net worth of farms in south-central Kansas in 2009 of \$507/acre (KFMA, 2010). This results in an upper ARAC of 0.0079.

Sensitivity Analysis

After the SERF analysis was performed, sensitivity analysis was conducted by changing herbicide costs, fertilizer costs, and corn yields. The SERF analysis ranks the systems according to preference at various risk aversion levels. As will be shown later, one system was preferred over all other systems at every level of risk aversion. The second most preferred system was also preferred over all others at every level of risk aversion. The percentage increase in 2011 glyphosate price of \$25.65/gallon that would make the second most preferred system's average net return equivalent to the most preferred system's average net return from the original SERF analysis was determined. Once this was done, SERF was conducted again. The percentage decrease in urea and DAP prices from the 2011 prices of \$448/ton for urea and \$508/ton for DAP that would make a less preferred system's average net return equivalent to the most preferred system's average net return from the original SERF analysis was determined. Once this was complete, SERF analysis was performed.

Because new corn varieties may potentially increase corn yields in the near future, the percentage increase in average corn yield that would cause the average net return from a system containing corn to be equivalent to the most preferred system's average net was determined. Once this was performed, SERF was conducted again.

An alternative series of commodity prices was used to simulate net returns for the SERF analysis. Annual commodity price projections from the Food and Agricultural Policy Research Institute (FAPRI) for the marketing years 2012 through 2016 were used and compared with the SERF results from the marketing year commodity price series from 2006 through 2010 (FAPRI, 2012).

Results

Yields by Cropping System

To understand fully the results of the net return distributions discussed later, it is important to examine and understand the yields for each crop rotation and tillage system. Annual yields are reported in Table 3.

Significant differences ($\alpha = 0.05$) between 10-year means were determined using analysis of variance procedures, assuming years were random representations of possible growing conditions for this location. Wheat yields after soybeans were statistically significantly greater from those produced in rotation with grain sorghum or the continuous wheat systems (Table 3). They were not statistically different from wheat yields in the wheat-corn rotation. Wheat yields in the wheat-corn rotation using no-tillage were statistically significantly greater than continuous

Table 3. Annual Crop Yields and Summary Statistics

System	RTWS	RTWS	NTWS	NTWS	RTGG	NTGG	RTWW	NTWW
Crop	Wheat	Soybean	Wheat	Soybean	Sorghum	Sorghum	Wheat	Wheat
1997	79	50	84	51	90	86	77	59
1998	49	22	51	22	98	94	42	44
1999	45	36	55	34	72	71	14	29
2000	54	25	65	20	84	87	41	44
2001	45	12	48	14	47	47	40	37
2002	55	19	50	21	51	51	53	46
2003	59	8	59	8	42	45	44	57
2004	53	52	57	50	116	126	67	72
2005	74	31	69	28	67	66	26	44
2006	63	32	64	39	65	59	60	66
Mean[a]	58[a]	29[a]	60[a]	29[a]	73[b]	73[b]	46[c]	50[bc]
SD	11	14	11	15	24	25	19	13
CV	20	50	18	52	32	35	40	27
Min	45	8	48	8	42	45	14	29
Max	79	52	84	51	116	126	77	72

System	RTWG	RTWG	NTWG	NTWG	RTWC	RTWC	NTWC	NTWC
Crop	Wheat	Sorghum	Wheat	Sorghum	Wheat	Corn	Wheat	Corn
1997	53	116	36	121	84	122	89	102
1998	43	105	42	108	51	48	45	52
1999	31	86	42	98	43	75	49	69
2000	33	115	37	109	48	99	42	93
2001	41	55	37	60	48	44	49	31
2002	56	58	48	57	49	45	51	47
2003	59	43	69	51	60	37	70	38
2004	65	157	66	146	69	138	67	135
2005	51	81	51	81	58	85	55	74
2006	63	67	54	74	65	70	61	62
Mean[a]	49[c]	88[a]	48[c]	91[a]	58[ab]	76[a]	58[a]	70[b]
SD	12	35	12	31	12	35	14	32
CV	24	40	24	34	21	46	25	46
Min	31	43	36	51	43	37	42	31
Max	65	157	69	146	84	138	89	135

[a] Means within a crop followed by the same letter are not significantly different (a = 0.05).
CV, coefficient of variation.

wheat yields. Wheat yields in the wheat-corn rotation were statistically greater than wheat yields in the wheat-grain sorghum rotation. Wheat yields rotated with grain sorghum were not statistically different from those from continuous wheat. Grain sorghum yields were statistically significantly greater when rotated with wheat for both reduced-till and no-till than from continuous cropping of grain sorghum.

Yields by Tillage System

Tillage system had very little effect on wheat yield. As shown in Table 3, there is only an approximate four bushel per acre difference between the two-monoculture wheat systems: reduced-till continuous wheat (RTWW) and no-till continuous wheat (NTWW). There is a one bushel per acre difference between wheat yields in reduced-till wheat-grain sorghum (RTWG) and no-till wheat-grain sorghum (NTWG). These differences are not statistically significant. Average wheat yields in the reduced-till wheat-corn (RTWC) and no-till wheat-corn (NTWC) systems were both approximately 58 bushels/acre (Table 3). The difference between wheat yields in RTWS (reduced-till wheat-soybean) and NTWS (no-till wheat-soybean) was not statistically significant.

Tillage system selection was also found to have minimal effect on soybean and grain sorghum yields. As Table 3 indicates, average soybean yield was approximately 29 bushels/acre for both RTWS and the NTWS rotations. Average yields for the continuous grain sorghum were 73 bushels/acre for both the reduced-till and no-till systems. There was a three bushel per acre difference in sorghum yield between RTWG and NTWG. None of these differences were statistically significant. Average corn yields were 76 bushels/acre for the RTWC system and 70 bushels/acre for the NTWC. This difference was statistically significant.

Overall Yield Comparison

Table 3 shows NTWS as the system with the greatest wheat yield, while RTWW had the smallest wheat yield across all the systems. The greatest grain sorghum yield occurred with the NTWG system, while the smallest grain sorghum yield was from the reduced-till continuous grain sorghum (RTGG) and no-till continuous grain sorghum (NTGG) systems. The largest corn yield was from the RTWC system as opposed to NTWC. Last, 10-year average soybean yields for RTWS and NTWS were separated by less than 0.10 bushels/acre.

Costs by Cropping System

The RTWS and NTWS systems have substantially lower total costs than any of the other systems. As shown in Table 4, which shows the total costs for each system by category, RTWS and NTWS required less nitrogen fertilizer than the other systems, with fertilizer costs for these systems being $38.07/acre. All of the other systems have fertilizer costs ranging from $69.82 to $71.84/acre. Aside from the RTWW system, RTWS also has lower herbicide costs compared with the other systems. NTGG, NTWG, and NTWC have the highest herbicide costs. Tillage costs were highest for the RTWW system: approximately $41/acre. Ignoring the no-till systems, RTWS, RTWG, and RTWC all have tillage costs of approximately $20/acre.

Costs by Tillage System

A comparison of total costs by tillage system shows that for the systems with a crop rotation as opposed to continuous cropping, no-tillage results in higher total costs than reduced tillage (Table 4). This is due to the additional herbicide applications used in the no-tillage system. The cost of herbicides plus application costs in the no-till systems are greater than the cost of herbicides with application plus tillage costs in the reduced tillage systems. Fertilizer, harvest, and seed costs are nearly the same for each system. For the continuous cropped systems, the cost of herbicides plus application costs in the no-till systems are less than the cost of her bicides with application plus tillage costs in the reduced tillage systems.

Overall Cost Comparison

RTWS and NTWS have the lowest total costs of all the systems at $154.17/acre and $156.43/acre,

Table 4. Summary Cost Statistics ($/acre)

Systems	RTWS	NTWS	RTGG	NTGG	RTWW	NTWW	RTWG	NTWG	RTWC	NTWC
Costs										
Tillage	$20.34	$0.00	$29.72	$0.00	$40.88	$0.00	$20.34	$0.00	$19.19	$0.00
Planting	$15.26	$15.79	$14.96	$16.03	$15.56	$15.56	$15.26	$15.79	$15.26	$15.79
Seeds	$28.77	$28.77	$10.34	$10.34	$19.88	$19.88	$15.11	$15.11	$36.87	$36.87
Chemicals application	$5.77	$14.75	$5.13	$11.54	$2.57	$16.67	$4.49	$14.75	$5.13	$14.11
Chemicals	$8.59	$22.06	$25.88	$38.41	$5.93	$25.51	$14.21	$32.39	$14.87	$31.83
Chemicals (applic. + inputs)	$14.36	$36.81	$31.01	$49.95	$8.50	$42.18	$18.70	$47.13	$20.00	$45.94
Fertilizer Application	$2.50	$2.50	$4.99	$4.99	$4.99	$4.99	$4.99	$4.99	$4.99	$4.99
Fertilizer	$38.07	$38.07	$69.82	$69.82	$71.05	$71.05	$70.44	$70.44	$71.84	$71.84
Fertilizer (applic. + inputs)	$40.56	$40.56	$74.81	$74.81	$76.04	$76.04	$75.43	$75.43	$76.83	$76.83
Harvest[a]	$28.94	$29.20	$32.51	$32.52	$28.10	$28.80	$32.35	$32.46	$28.96	$29.00
Interest	$5.93	$5.29	$6.77	$6.43	$6.61	$6.39	$6.20	$6.51	$6.90	$7.16
Total cost	$154.17	$156.43	$200.12	$190.07	$195.56	$188.84	$183.39	$192.43	$204.01	$211.58

[a] Based on 10-year average crop yield.

respectively (Table 4). The RTWG system has the next-lowest total cost of $183.39/acre followed closely by the NTWW system with total cost of $188.84/acre. The systems with the highest total cost are the NTWC and RTWC systems at $211.58 and $204.01/acre, respectively (Table 4).

Simulated Net Return Distributions

Analysis was conducted using the simulated 5-year 2006 through 2010 and 10-year 1997 through 2006 annual crop prices. Table 2 reports the price distribution characteristics for each period. The average simulated crop prices were higher for 2006 through 2010 than for the 1997 through 2006 period. The variability was higher as well.

Table 5 contains a summary of the average simulated net returns for the two price series. NTWS has the highest net returns for each price series, followed closely by RTWS. The NTWS and RTWS systems are the two most profitable cropping systems because they have both the highest gross returns and lowest total costs of the 10 systems. RTWG has the next highest net returns, followed by the NTWG. The continuous or monoculture grain sorghum and wheat systems are the least profitable with the 2006 through 2010 price series.

The CDFs of net returns in tabular cumulative probability format using 5% increments are presented in Table 6 for the 2006–2010 commodity price series. For example, there is a 40% probability that RTWS will have a net return equal to or less than $99.53/acre and a 60% chance it will be above this value. RTWS and NTWS have higher net returns at all levels of cumulative probability up to 95% percent. At a cumulative probability of 96% and greater, the values are larger for RTWC than RTWS. The maximum values from NTGG and NTWC are larger than that of RTWS and the maximum values for RTWC and NTWC are larger than that of NTWS. The net returns for NTWS are generally larger between the minimum and cumulative probability of 18% and then from 54% through the maximum value. The CDFs for RTWS and NTWS cross several times between 18% and 38%, while net returns for RTWS are higher between 38% and 54% cumulative probability. These results indicate that risk neutral and risk-averse managers should prefer RTWS and NTWS to all other systems.

Table 5. Simulated Net Return Characteristics for Annual Price Series ($/acre)

	System	RTWS	NTWS	RTGG	NTGG	RTWW	NTWW	RTWG	NTWG	RTWC	NTWC
2006 to 2010 Price Series	Mean	$138.21	$142.37	$68.93	$78.50	$63.52	$88.80	$115.86	$106.57	$105.41	$86.98
	SD	$96.05	$101.54	$81.51	$81.90	$113.92	$97.37	$82.50	$72.30	$105.24	$97.84
	CV	0.69	0.71	1.18	1.04	1.79	1.10	0.71	0.68	1.00	1.12
	Min	−$24.67	−$21.36	−$63.27	−$46.47	−$124.88	−$50.63	−$39.37	−$23.84	−$46.34	−$65.69
	Max	$423.98	$436.36	$376.39	$434.19	$331.11	$304.62	$413.71	$394.43	$437.63	$442.13
1997 to 2006 Price Series	Mean	$20.58	$22.16	−$41.83	−$32.12	−$41.92	−$24.23	−$6.70	−$15.55	−$25.45	−$38.67
	SD	$53.16	$56.36	$45.32	$45.66	$63.18	$53.66	$44.54	$40.19	$55.30	$52.28
	CV	2.58	2.54	NA	NA	NA	NA	NA	NA	NA	NA
	Min	−$66.69	−$65.29	−$110.30	−$96.15	−$148.00	−$98.08	−$88.70	−$82.71	−$102.43	−$117.44
	Max	$218.71	$226.04	$178.89	$207.41	$148.10	$133.65	$206.66	$165.23	$187.35	$181.12

CV, coefficient of variation.

SERF Results

SERF analysis indicates that NTWS is the preferred system over the entire range of risk aversion for the 2006–2010 commodity price scenario (Figure 1). NTWS is the preferred system, followed by RTWS, and RTWG, NTWG, and RTWC. However, the difference in preference measured by risk premiums between NTWS and RTWS is small. At an ARAC of zero, or risk neutrality, RTWS requires an additional $4.16/acre to be equally preferred to NTWS. This value declines to $1.40/acre at an ARAC of 0.0079. The differences between the NTWS and other systems are larger. At an ARAC of zero, showing risk-neutral preferences, RTWG requires an additional $26.51/acre and declines to $16.64/acre at an ARAC of 0.0079 to be equally preferred to NTWS.

For the 1997 through 2006 annual commodity price series (Figure 2), the results are very similar. NTWS is the preferred system. RTWS requires only an additional $1.58/acre to be equally preferred to NTWS at an ARAC of zero and the required amount declines to $0.54/acre at an ARAC of 0.0079. RTWG is the next-preferred system with an additional $28.87/acre needed to be equally preferred to NTWS at an ARAC of zero and $24.91/acre at an ARAC of 0.0079.

SERF Tillage Preference by Rotation

The following risk analysis results are consistent across both price scenarios. RT is preferred to NT for wheat-grain sorghum and wheat-corn crop rotations across all levels of risk aversion. NT is preferred to RT for wheat-soybean, continuous wheat, and continuous grain sorghum crop rotations across all levels of risk aversion.

SERF Crop Rotation Preference by Tillage System

Wheat-soybean is the preferred crop rotation if either RT or NT is used with either price scenario across all levels of risk aversion. Wheat-grain sorghum is the second preferred crop rotation if either RT or NT is used with either price scenario across all levels of risk aversion.

Table 6. Net Returns in 5% Cumulative Probability Increments for 2006–2010 Price Series

System	RTWS	NTWS	RTGG	NTGG	RTWW	NTWW	RTWG	NTWG	RTWC	NTWC
Cumulative Probability										
Minimum	−$24.67	−$21.36	−$63.27	−$46.47	−$124.88	−$50.63	−$39.37	−$23.84	−$46.34	−$65.69
0.05	$7.65	$9.31	−$46.14	−$32.09	−$111.62	−$42.83	−$5.28	$3.07	−$22.96	−$36.37
0.10	$23.93	$24.65	−$33.96	−$19.81	−$85.55	−$25.27	$16.00	$18.93	−$12.17	−$21.96
0.15	$37.53	$39.00	−$16.35	−$3.57	−$58.59	−$8.78	$28.99	$33.53	$1.18	−$8.43
0.20	$50.96	$50.96	$1.10	$8.27	−$31.41	$8.00	$41.82	$46.22	$11.79	$2.54
0.25	$61.80	$60.96	$8.92	$16.87	−$9.48	$15.00	$54.18	$54.88	$23.31	$12.16
0.30	$75.22	$72.92	$18.28	$26.12	−$1.80	$21.68	$66.86	$62.45	$33.90	$21.08
0.35	$85.60	$85.30	$24.74	$35.99	$7.74	$30.65	$76.31	$71.43	$43.88	$33.12
0.40	$99.53	$98.89	$34.38	$45.12	$16.33	$39.25	$85.49	$80.52	$55.49	$44.05
0.45	$111.44	$108.79	$46.97	$55.98	$30.91	$51.20	$95.10	$89.01	$67.63	$54.32
0.50	$123.10	$122.14	$58.97	$68.94	$44.40	$66.06	$107.44	$96.26	$79.63	$65.99
0.55	$136.98	$137.33	$71.02	$75.10	$60.94	$80.54	$119.84	$106.66	$96.41	$78.50
0.60	$148.10	$153.19	$83.39	$86.65	$80.93	$96.81	$131.29	$115.66	$111.77	$91.50
0.65	$163.52	$168.64	$94.53	$95.48	$95.24	$112.46	$142.24	$123.32	$128.85	$106.18
0.70	$181.73	$186.19	$107.98	$108.81	$114.36	$130.20	$154.21	$135.38	$145.53	$124.41
0.75	$198.59	$206.76	$123.19	$126.68	$140.75	$153.17	$167.39	$148.75	$166.51	$145.40
0.80	$223.16	$235.40	$137.13	$146.34	$163.65	$179.50	$180.87	$165.02	$192.91	$166.98
0.85	$245.50	$261.17	$147.32	$170.09	$188.21	$212.16	$199.28	$180.32	$223.18	$192.05
0.90	$277.30	$293.99	$167.10	$186.99	$229.48	$243.49	$225.28	$207.88	$258.88	$225.87
0.95	$319.84	$335.66	$223.39	$232.21	$284.40	$281.29	$271.05	$245.37	$318.03	$279.92
Maximum	$423.98	$436.36	$376.39	$434.19	$331.11	$304.62	$413.71	$394.43	$437.63	$442.13

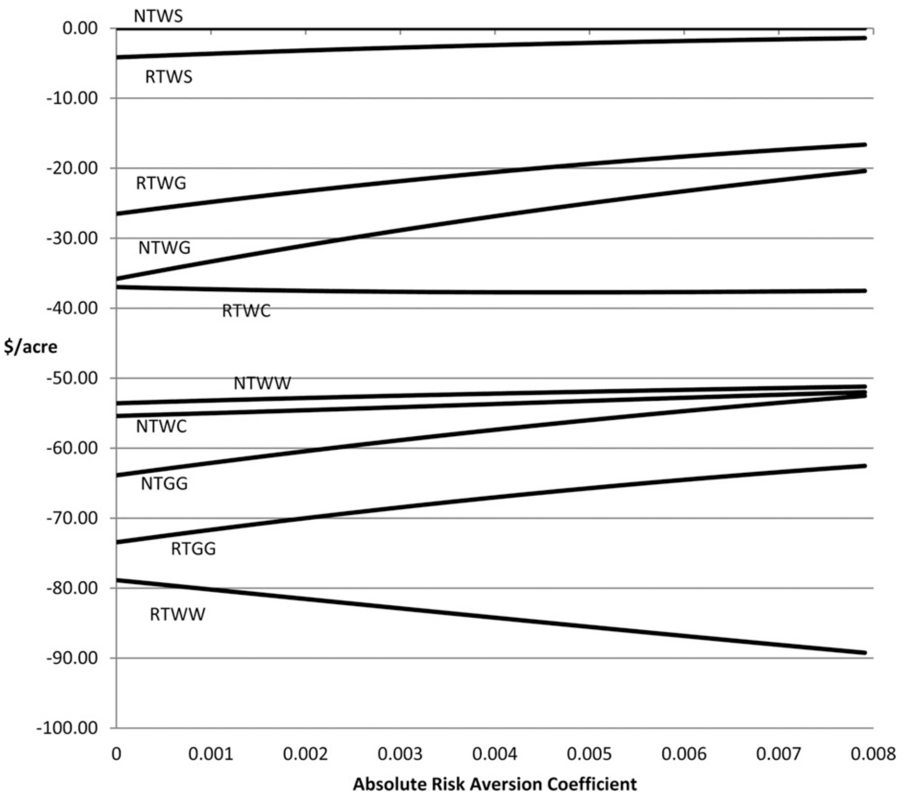

Figure 1. Risk Premiums Relative to NTWS for Simulated Net Returns Using 2006–2010 Commodity Prices

Herbicide Cost Sensitivity Analysis

Glyphosate is the predominant herbicide used in the no-tillage systems. Over the last few years, herbicide prices, especially glyphosate-based products, have been quite variable. Therefore, a sensitivity analysis was conducted using the 2006–2010 commodity price scenario to determine the percentage increase in glyphosate price where RTWS net return was equivalent to NTWS. The 2011 glyphosate price used in the original analysis was $25.65/gallon. This is a low price relative to the average price of $41.52 /gallon ($47.37/gallon in 2011 dollars) for 2001 through 2010. A 55.4% increase in glyphosate price, to $39.86/gallon, resulted in RTWS average returns equal to NTWS. RTWS became the more profitable system for any glyphosate price above the $39.86/gallon. According to USDA NASS (2011b) this has happened six times (seven times in 2011 dollars) in the last 10 years, although the 2010 price was significantly lower. RTWS was the preferred system at all levels of risk aversion. The maximum risk premium compared with NTWS was $3.08/acre at an ARAC of 0.0079. The maximum risk premium in the original analysis was $4.16/acre at an ARAC of 0.0 and the risk premium declined to $1.40/acre at an ARAC of 0.0079.

Although glyphosate is the most commonly used herbicide in the cropping systems, several other herbicides are also used. Therefore, the percentage increase in all herbicide prices that resulted in the RTWS system net return being equivalent to NTWS was determined. A 25.7% increase in all herbicide costs resulted in RTWS having average returns equal to NTWS. RTWG had the third highest average net returns, while RTWC moved from fifth to fourth ahead of NTWG. SERF indicated RTWS was preferred at all levels of risk aversion at this increase in herbicide prices. The maximum risk premium compared with NTWS was $2.85/acre at an ARAC of 0.0079. RTWG was preferred to all

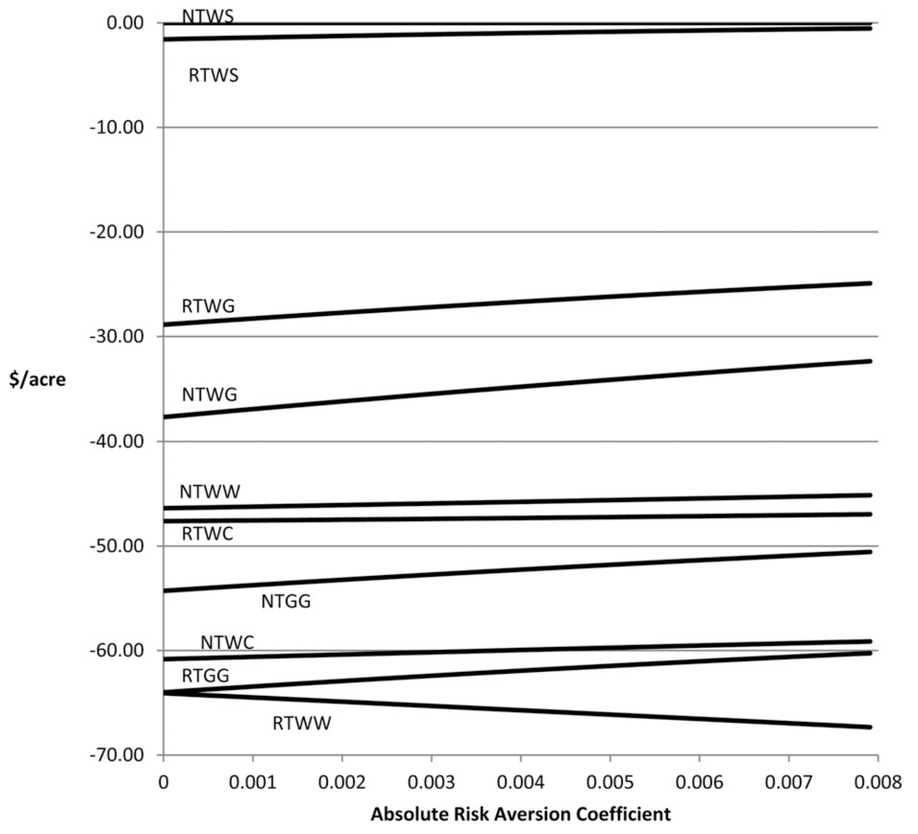

Figure 2. Risk Premiums Relative to NTWS for Simulated Net Returns Using 1997–2006 Commodity Prices

other systems at all levels of risk aversion with the exception of RTWS and NTWS.

Fertilizer Costs Sensitivity Analysis

In the past few years fertilizer prices also have shown considerable variability. To evaluate the effect of fertilizer prices on the net returns, a sensitivity analysis was conducted. The percentage decrease in urea and DAP prices from the 2011 prices of $448/ton for urea and $508/ton for DAP that would make a cropping system without soybeans average net return equivalent to the most preferred system's average net return from the original SERF analysis was determined. Once this was done, SERF was conducted again. The wheat-soybean cropping systems which are the two most preferred systems use less fertilizer than any of the other systems because soybeans only receive 20 pounds per acre of starter fertilizer. Because of this, increases in fertilizer cost would improve these systems net returns relative to the other cropping systems. Therefore, the decrease in fertilizer cost that is needed for the RTWG system, which is the third most preferred system, to have the same average net return as NTWS using the 2006–2010 commodity price series was determined. Fertilizer costs would have to decline 84.5 percent for RTWG to have equivalent net returns to NTWS. With this decrease in cost, RTWG is also preferred to NTWS at all levels of risk aversion. The resulting cost of urea and DAP would need to be $69.44/ton and $78.74/ton in 2011 dollars, respectively. The fertilizer prices never approached these low levels in either nominal or 2011 dollars prices from the beginning of the study period to 2011 (USDA NASS, 2012).

Corn Yield Sensitivity

The commercial release of drought-resistant corn varieties, tentatively scheduled for 2012 by several companies, may affect these results and make corn a more viable production option. Kaskey and Ligi (2010) note these varieties may increase corn yields in dry areas by 6 to 10%, which could cause producers to switch to corn, particularly if corn stocks remain low and prices remain high.

Under the 2006–2010 commodity price series, given all other original conditions we determined that a 26% increase in corn yield would be needed for a wheat-corn rotation (RTWC) to have the same average net return as NTWS. However, SERF analysis indicates that NTWS would be preferred by all risk-averse decision-makers (at ARACs above 0.00). Corn prices would have to increase relative to soybean prices in addition to yield growth to increase the likelihood of using a wheat-corn rotation.

Results with Forecasted Commodity Prices

Annual commodity price projections from the FAPRI for the marketing years 2012 through 2016 were used and compared with the SERF results from the marketing year price series from 2006 through 2010 (FAPRI, 2012). The SERF results were similar. The NTWS system was preferred over all other systems at all levels of risk aversion. RTWS was the second most preferred system at all levels of risk aversion. RTWG and NTWG were the third and fourth most preferred systems. These four systems had the same ranking that occurred under the 2006 through 2010 price series. However, the risk premiums for RTWG compared with NTWS were \$11.65/acre to 12.35/acre smaller depending upon level of risk aversion. The risk premiums for NTWG were \$12.94/acre to \$13.18/acre less. This indicates that systems with grain sorghum had their net returns improve relative to other systems. Further, the NTGG system improved from eighth to fifth while RTGG moved from ninth to seventh. RTWC moved from fifth to sixth and NTWC moved from seventh to eighth. NTWW moved from sixth to ninth and RTWW was the least preferred system as it was previously.

Machinery Costs

Some machinery costs could be understated with the use of custom rates. The implications are that cropping systems that use more tillage may have relatively higher costs relative to no-till systems than reflected in this study, if farm managers own and operate their own equipment for tillage. This would also be true for planting, but all cropping systems compared have one planting operation each year so the relative comparison using custom rates is valid. Tillage and planting custom rates data are likely to be based more on neighbors and relatives who may charge at least enough to cover all operating costs but not necessarily all ownership costs. There is a large amount of custom application of herbicides and custom harvesting in this region. Many of these operations are performed by custom applicators and harvesters covering all costs to earn a profit. Therefore, the cost for applying chemicals and harvesting of crops by custom harvesters are appropriate. Farm managers also hire custom operators when it is cheaper and timelier for them to do so.

Summary and Conclusions

Simulated net returns were estimated and compared using two historical price series, 2011 production costs, and historical yields for 10 cropping systems. Risk analysis was also conducted using stochastic efficiency with respect to a function. Sensitivity analysis was conducted on herbicide and fertilizer prices to see how the relative net returns and risk preference of each system would change.

NTWS has the highest average net returns for both historical commodity price series used, with RTWS having the second-highest net return for each price distribution. RTWG and NTWG had the next-highest net returns. RTWS and NTWS were the lowest cost systems. Total costs were also relatively low for RTWG. NTWS remained the most profitable system up to an approximately 55% increase in glyphosate price. Changes in fertilizer costs did not change the rank order of systems by highest net return.

SERF analysis indicates NTWS is the system most preferred regardless of the level of risk aversion. RTWS is the second most preferred system at all levels of risk aversion. However, the risk premiums are small. These results also occurred when forecasted commodity prices were used.

Although the results will apply to future years only if the relative costs, the means and variability of yields, and future crop prices are similar to the empirical data, the analysis indicates that there is potential to rotate soybeans with wheat in an area where wheat has been continuously grown or rotated with grain sorghum. This is consistent with the increase in soybean acreage and reduction of wheat acres in the region.

The row crop-wheat rotations generally have higher net returns and are generally preferred at all levels of risk aversion than the continuous cropping systems. Additionally, cropping systems with soybeans use less fertilizer that has generally increased in cost. Therefore, extension educators should place additional emphasis on the advantages of rotating a row crop, particularly soybeans with wheat for increasing net returns and reducing risk. Policies to encourage no-tillage may not be as important as in the past if energy prices continue to rise as no-tillage has generally been shown to be less energy intensive. Further, no-tillage requires fewer field operations than systems with tillage. As a result, managers may be able to farm more acres with no-tillage, leading to an increase in whole-farm net returns over time.

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