An Economic Risk Analysis of No-till Management for the Rice-Soybean Rotation System used in Arkansas

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Abstract

Arkansas is the top domestic rice producer, representing nearly half of total U.S. rice production. Sediment is one of the major pollutants in rice producing areas of Arkansas. In order to mitigate this problem no-tillage management is often recommended. No-tillage is not well understood by farmers who believe that no-till is less profitable due to lower yields offsetting cost savings. This study evaluates the profitability and variability of no-till in the typical rice-soybean rotation used in Arkansas rice production. Crop yields, prices and prices for key production inputs (fuel and fertilizer) are simulated for the rotation, and net return distributions for rice, soybean and the two-year rotation are evaluated for no-till and conventional till using stochastic efficiency with respect to a function (SERF) analysis. The results indicate that both risk neutral and risk-averse rice producers would prefer no-till over conventional till management in the two year rice-soybean rotation, and that no-till soybeans contribute greatly to the overall profitability of the rotation.

Introduction

Arkansas is the leading rice producing state in the United States, accounting for over 45% of total US rice production in 2009 (USDA, ERS 2011). Historically, rice has been of great importance for the Arkansas economy. Rice is Arkansas' highest valued crop, accounting for 37% of crop production value for the state in 2010 (USDA, NASS 2011). Approximately 0.722 million hectares of rice were harvested in 2010 in Arkansas, yielding approximately 7,263 kg/ha and producing about 5.25 billion kilograms of rice. Arkansas's 2010 rice production was valued at approximately $1.3 billion (USDA, NASS 2011).

Rice is typically rotated with soybeans in Arkansas. Although rice is a more profitable crop than soybean, the latter crop is generally rotated with rice as a means of controlling red rice, a close weed relative to rice. A two-year rice-soybean rotation is typical for most rice acreage in Arkansas. In 2009, the rice-soybean rotation accounted for almost 68% of Arkansas rice acreage (Wilson et al. 2009). However, some acres may be continuous rice or rotated with other crops such as corn, sorghum, cotton, and wheat (Wilson et al. 2009).

Nearly all rice is produced in the eastern part of Arkansas along the Mississippi Delta region. Agriculture, geography, and climate have major impacts to surface water quality in eastern Arkansas. According to Kleiss et al. 2000, eastern Arkansas soils are predominantly composed of dense alluvial clay sub-soils that limit water infiltration. Surface soils contain slit and clay particles that are moved by heavy rainfall from tilled fields, and these soils also contain little organic matter (Huitink et al.1998). Sediment is the primary pollutant identified for most eastern Arkansas waterways, and conservation practices like no-tillage (NT) are commonly recommended as remedial mechanisms (Huitink et al. 1998). While conventional-till (CT) is

cultivation intensive, NT provides maximum erosion control, conserves soil moisture, improves soil organic matter, and has lower fuel and labor input costs (USDA NRCS 2006).

Conventional rice production in Arkansas involves intensive cultivation. Fields are "cut-to-grade" every few years, disked annually in either late fall or early spring, and "floated" (land planed) annually in early spring to ensure smooth water movement across the field. In 2009, conventional till (spring tillage and floating) accounted for 52.5% of all planted rice acres in Arkansas, while stale seedbed (fall tillage followed by burn-down herbicides prior to planting in the spring) accounted for over 35.3% of planted rice acres. True NT management (rice planted directly into the previous crop residue without tillage at any time) accounted for 12.2% of planted Arkansas rice acres in 2009 (Wilson et al. 2009).

The profitability of NT rice has been investigated using enterprise budget analysis (Hignight et al., 2009), whole-farm analysis (Watkins, et al., 2006) and risk analysis from the perspectives of both the landlord and the tenant in typical Arkansas tenure arrangements (Watkins et al. 2008). Hignight et al. 2009 evaluated the economic contributions of both rice and soybean to the rotation under NT management but did not conduct a risk analysis. The two other studies looked solely at returns to the rice-soybean rotation under no-till management and did not evaluate the economic contributions made by either rice or soybean to the rotation. The Watkins et al. 2008 study also considered only price and yield risk and did not evaluate systematic production cost risk associated with high and volatile fuel and fertilizer prices**.** Rice in particular is a high-cost crop relative to other field crops due to its large fuel, fertilizer, and irrigation expenses (Childs and Livezey 2006).

The objective of this study is to evaluate the profitability and risk efficiency of NT relative to CT management for the typical rice-soybean production system used in Arkansas rice

production. Crop yields, crop prices, and prices for key production inputs (diesel and fertilizer) are simulated, and net return distributions for rice, soybean, and the two-year rotation are evaluated separately for both NT and CT management using stochastic efficiency with respect to a function (SERF).

Materials and Methods

Crop yields, crop prices, and prices for fuel and fertilizer were simulated using the Excel Add-In, SIMETAR (Richardson et al. 2008). Multivariate empirical distributions (MVEs) were used to simulate 500 iterations of yields and prices. A MVE distribution simulates random values from a frequency distribution made up of actual historical data and has been shown to appropriately correlate random variables based on their historical correlation (Richardson et al. 2000). Parameters for the MVE include the means, deviations from the mean or trend expressed as a fraction of each variable, and the correlation among variables. The MVE distribution is used in instances where data observations are too few to estimate parameters for another distribution (Pendell et al. 2006).

Rice and soybean yield distributions under CT and NT were simulated using eleven years of historical yield data from a long term rice-based cropping systems study at Stuttgart, Arkansas for the period 2000-2010 (Anders and Hignight 2010). The historical crop yields represent yields obtained in a two-year rice-soybean rotation. Deviations from 11-year means were used to estimate the parameters for the MVE yield distributions, and mean yields over the 11-year period were used as expected yields for the MVE yield distributions. Summary statistics for the simulated yields are presented table 1. Rice yields for NT are lower by approximately 300kg/ha than CT rice yields. Soybean yields for NT on the other hand are higher for about 100kg/ha for

NT than CT soybean. Anders and Hignight (2009), also found that, over time, NT rice yields declined compared to CT, while NT soybean yields steadily increased compared to CT.

Multivariate empirical distributions were used to simulate crop prices (rice, soybean) and prices for key production inputs (diesel, urea, phosphate, and potash). All price simulations were based on historical prices obtained from the USDA, National Agricultural Statistics Service (2002, 2006, 2009, 2010 a,b) for the 2000-2010 period, adjusted to 2010 dollars using the Producer Price Index. Deviations from the means and their associated correlations were used to simulate the MVE price distributions for each price series, but mean prices for the period 2005-2010 were used rather than 11-yr means to represent expected prices for the MVE price distributions. Prices for the latter five years of the 11-yr period better represent current farmer price expectations. The MVE approach has been shown to reproduce the historical correlation matrix and maintain the historical coefficient of variation from the original historical data series even when using means different from the historical mean (Ribera et al. 2004). Summary statistics for simulated prices are presented in table 1.

Direct and fixed expenses for the analysis were based on cost data used in the 2010 Arkansas Rice Research Verification Program (Runsick et al. 2010) and input data for rice and soybeans grown in a two-year rotation obtained from the long term rice cropping systems study at Stuttgart, Arkansas. Direct expenses included expenses associated with fertilizer, pesticides, seed, operator labor, machinery and irrigation fuel, machinery and irrigation repairs and maintenance, and interest on operating capital. Fixed expenses included machinery and irrigation depreciation and interest. Average budgeted expenses are presented by crop enterprise and tillage method on a per hectare basis in table 2. NT is less labor and machinery intensive, therefore it is a fuel saving practice, but it requires more herbicide and custom chemical/fertilizer

applications. Average direct expenses for NT rotation were found to be $978.58/ha, while CT rotation average direct expenses were $996.21/ha. NT fixed expenses were also found to be lower on average than CT rotation fixed expenses ($162.04/ha for Nt; $194.09/ha for CT). Consequently, total expenses for NT rotation were lower on average than those for CT rotation ($1140.62/ha for NT; $1190.30/ha for CT).

Using the above data, net returns per hectare for the rice-soybean rotation were estimated based on the 500 simulated iterations using the following formula:

$$NR_j = 0.5 * \sum_{i=1}^{2} \left\{ \left(Y_{ij} * P_{ij} \right) - SVC_{ij} - SHC_{ij} - NSVC_i - F_i \right\} \qquad 1)$$

where

i = 1 to 2 crops (rice, soybean);

j = 1 to 500 simulated iterations;

NR_j is the total net revenue per hectare of the rice-soybean rotation for iteration j;

Y_{ij} is the stochastic yield per hectare of crop i and iteration j;

P_{ij} is the stochastic price per kilogram for crop i and iteration j;

SVC_{ij} is the total stochastic variable cost of fuel and fertilizer per hectare of crop i and iteration j;

SHC_{ij} is the total stochastic harvest cost per hectare of drying, check off and hauling for crop i and iteration j;

$NSVC_i$ is the total non-stochastic variable cost per hectare for crop i; and

F_i is the fixed cost per hectare for crop i.

Equation 1 is multiplied by 0.5 to reflect a rotation of 50% rice and 50% soybeans.

Risk analysis was conducted using the SERF method. The SERF method is a variant of stochastic dominance with respect to a function (SDRF) that orders a set of risky alternatives in

terms of certainty equivalents (CE) calculated for specified ranges of risk attitudes (Hardaker et al. 2004). The CE is equal to the amount of certain payoff an individual would require to be indifferent between that payoff and a risky investment. The CE is typically less than the expected (mean) monetary value and greater than or equal to the minimum monetary value of a stream of monetary outcomes (Hardaker et al. 2004).

The SERF method allows for simultaneous rather than pairwise comparison of risky alternatives (Hardaker et al. 2004). Graphical presentation of SERF results facilitates the presentation of ordinal rankings for decision makers with different risk attitudes and provides a cardinal measure of a decision maker's conviction for preferences among risky alternatives at each risk aversion level by interpreting differences in CE values for a given risk aversion level as risk premiums (Hardaker et al. 2004).

The SERF method calls for calculating CE values over a range of absolute risk aversion coefficients (ARACs). The ARAC represents a decision maker's degree of risk aversion. Decision makers are risk averse if ARAC > 0, risk neutral if ARAC = 0, and risk preferring if ARAC < 0. The ARAC values used in this analysis ranged from 0 (risk neutral) to 0.0068 (strongly risk averse). The upper ARAC value was calculated using the following formula proposed by Hardaker et al. 2004:

$$ARAC_w = \frac{r_r(w)}{w} \qquad 2)$$

where

$r_r(w)$ is the relative risk aversion coefficient with respect to wealth (w). As proposed by Anderson and Dillon 1992 $r_r(w)$ was set equal to 4 (very risk averse). Wealth (w) was calculated based on the respective net returns means from CT Rice, NT Rice, CT Soybean, NT Soybean

and CT and NT rotations ($585.60/ha calculated from averaging mean net returns in table 3), following procedures outlined by Hardacker et al. 2004. Given the above formula and the above calculated wealth value, the ARAC upper bound was estimated to be ≈ 0.0068.

Absolute risk aversion coefficient values ranging from 0 (risk neutral) to 0.0068 (strongly risk averse) were used in the SERF analysis to calculate CE values for each of the rotation crops (rice, soybean) and for the rice-soybean rotation under CT and NT management. The Excel Add-In SIMETAR was used to conduct the SERF analysis based on a negative exponential utility function. Certainty equivalent graphs were constructed to display ordinal rankings of NT and CT across the specified range of ARAC values, and NT risk premiums were calculated for each crop and the rotation by subtracting CT CE values from NT CE values at given ARAC values.

Results and Discussion

Net Returns to Rice, Soybean, and the Rotation. Summary statistics of simulated net returns to rice, soybean, and the two-year rotation are presented by tillage method in table 3. Average returns to rice in the two-year rotation are slightly larger for CT than for NT, but the relative variability of returns to rice under the two tillage methods as measured by the coefficient of variation is equal. (CV = 70 for both CT rice and NT rice net returns, table 3). Average returns to soybean are lower than average returns to rice regardless of the tillage method used, implying rice is the more profitable crop in the two-year rotation. However, the soybean average returns are larger under NT than under CT management, and the relative variability of soybean returns is smaller for NT than for CT (CV = 73 for NT soybean; CV = 101 for CT soybean, table 3). Average returns for the two-year rotation are also slightly larger and less variable under NT management than under CT management. These results are due primarily to the soybean portion

of the rotation, which is both more profitable and less risky under NT management. In all three instances (rice, soybeans, and the rotation), the minimum and maximum returns are larger for NT than for CT. These results imply NT performs better than CT in both "poor" crop years (higher minimum returns) and "good" crop years (higher maximum returns) for both rotation crops and the rotation itself.

Certainty Equivalents, Risk Premiums, and Stochastic Efficiency with Respect to a Function. Certainty equivalents for rice, soybean, and the rotation are presented for various ARAC values by tillage method in table 4. No-tillage risk premiums for rice, soybean, and the rotation are also presented for various ARAC values in table 4 and mapped across ARAC values in figure 1. Certainty equivalents are equal to the mean (expected) net return when ARAC = 0 but decline as ARAC values become larger (e.g., as risk aversion increases). Certainty equivalents are initially larger for CT rice than for NT rice at ARAC values ranging from 0 to 0.0023 but become larger for NT rice than for CT rice at ARAC values greater than 0.0023. Thus, corresponding NT risk premiums for rice are initially negative at lower levels of risk aversion but become positive at higher levels of risk aversion, implying rice producers with a slight aversion to risk would tend to prefer CT rice while rice producers with a strong aversion to risk would tend to prefer NT rice (table 4, figure 1).

Certainty equivalents for soybean are everywhere larger for NT than for CT across ARAC values, and differences in CE values between NT and CT grow as ARAC values become larger. Thus, NT risk premiums for the soybean portion of the rotation are everywhere positive and increase in magnitude as ARAC values become larger, ranging from $48/ha for ARAC = 0 to $202/ha for ARAC = 0.0068 (table 4 and figure 1). Certainty equivalents for the two-year rotation are also everywhere larger for NT than for CT across ARAC values. Differences in CE

values between NT and CT for the rotation also grow as ARAC values become larger. Thus NT risk premiums for the rotation are everywhere positive and grow as the rice producer's risk aversion level becomes larger, ranging from $16/ha for ARAC = 0 to $49/ha for ARAC = 0.0068 (table 4 and figure 1).

Stochastic efficiency with respect to a function results for rice, soybean, and the rotation are presented by tillage method in figures 2, 3, and 4. Strategies that are risk preferred in all three figures would have the locus of points of highest CE values. The mapping of CE values for NT rice in figure 2 matches closely the mapping of CE values for CT rice, indicating no risk preference for either method based on SERF analysis. These results imply risk-averse rice producers would generally be indifferent between using either NT or CT management in rice production.

The SERF results for the soybean portion of the rotation are much different than those for the rice portion of the rotation (figure 3). The locus of CE values for NT soybeans is higher than that for CT soybeans for all comparisons, indicating risk-averse rice producers would prefer NT soybeans to CT soybeans. Similar results are found for the two-year rotation (figure 4). The locus of CE values for the NT two-year rotation is everywhere higher than that for the CT rotation. Thus, risk-averse rice producers would prefer NT to CT management in the traditional two-year rice-soybean rotation, based on results from this analysis.

Summary and Conclusions

This study evaluates the profitability and risk efficiency of no-till for the typical rice-soybean rotation used in Arkansas. Crop prices, yields and stochastic expenses are simulated and used to evaluate the profitability of no-till relative to conventional till production. Net return distributions for rice, soybean, and the two-year rotation are evaluated separately for both no-till

and conventional till management using stochastic efficiency with respect to a function (SERF). The results show no difference in stochastic returns between no-till and conventional till rice, and that risk-averse rice producers would be indifferent between using either tillage method in the rice portion of the rotation. However, no-till soybeans are both more profitable on average and have positive risk premiums relative to conventional till soybeans, indicating that both risk neutral and risk-averse rice producers would prefer no-till soybeans in the soybean portion of the rotation. No-till management is also more profitable on average and produces positive risk premiums over conventional till management for the overall rice-soybean rotation, implying that both risk neutral and risk-averse rice producers would prefer to use no-till over conventional till for the two-year rotation. These results indicate that no-till soybeans contribute greatly to the overall profitability of the rotation.

Besides being more profitable, no-till can reduce sediment run-off and contribute to improved water and soil conservation. Lower fuel emissions are also one of the many no-till benefits that results from lowered machine fuel usage. No-till management may also contribute to carbon sequestration in rice production. This study evaluates profitability only and does not seek to quantify environmental benefits of no-till management. Given the great interest in soil and water conservation practices, future studies should be conducted to measure such benefits.

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Table 1
Summary statistics of simulated yields and prices.

Variable	Mean*	SD	CV†	Minimum	Maximum
CT Rice Yield (kg/ha)	9,284	630	6.78	8,062	10,050
NT Rice Yield (kg/ha)	8,938	679	7.59	8,158	10,554
CT Soybean Yield (kg/ha)	3,162	977	30.89	1,122	4,430
NT Soybean Yield (kg/ha)	3,232	772	23.89	2,101	4,594
Rice Price ($/kg)	0.267	0.076	28.55	0.143	0.386
Soybean Price ($/kg)	0.334	0.062	18.51	0.240	0.435
Diesel Price ($/L)	0.654	0.206	31.47	0.408	1.132
Urea ($/kg)	0.477	0.095	19.91	0.315	0.634
Phosphate ($/kg)	0.519	0.201	38.74	0.375	1.151
Potash ($/kg)	0.515	0.278	53.91	0.315	1.299

Notes: CT = conventional till; NT = no-till.
*Summary statistics calculated from 500 simulated iterations.
†Coefficient of variation (CV) is a unitless measure of relative risk and is equal to 100 multiplied by the quotient of the standard deviation divided by the mean.

Table 2
Average direct and fixed expenses for a rice-soybean rotation by crop, rotation, and tillage, 2010 Dollars.

	Rice		Soybean		Rotation	
Expense Item	CT ($/ha)	NT ($/ha)	CT ($/ha)	NT ($/ha)	CT ($/ha)	NT ($/ha)
Seed	171.68	171.68	145.30	145.30	158.49	158.49
Fertilizers*	280.41	280.41	150.56	150.56	215.49	215.49
Agrotain	20.13	20.13	0.00	0.00	10.06	10.06
Herbicide	158.25	174.66	21.55	26.84	89.90	100.75
Insecticide	1.34	1.34	0.00	0.00	0.67	0.67
Custom Chemical and Fertilizer Application	93.91	93.91	42.63	63.94	68.27	78.93
Irrigation Supplies	18.41	18.41	4.82	4.82	11.61	11.61
Survey Levees	13.59	13.59	0.00	0.00	6.80	6.80
Labor	26.64	21.43	19.27	13.90	22.95	17.67
Diesel Fuel*	273.55	237.16	124.95	109.45	199.25	173.31
Repairs & Maintenance	53.65	50.31	29.37	27.02	41.51	38.66
Post-Harvest Expenses*	265.41	255.52	29.05	29.69	147.23	142.60
Interest on Operating Capital	32.15	31.27	15.80	15.82	23.98	23.54
Total Direct Expenses	1409.12	1369.82	583.30	587.33	996.21	978.58
Fixed Expenses	252.80	216.03	135.38	108.05	194.09	162.04
Total Expenses	1661.92	1585.85	718.68	695.38	1190.30	1140.62

Notes: CT = conventional till; NT = no-till.
*Expense item is stochastic (average calculated from 500 simulated iterations).

Table 3
Summary statistics of net returns for a rice-soybean rotation by tillage, crop, and rotation.

Variable	Mean*	SD	CV†	Minimum	Maximum
CT Rice ($/ha)	818	574	70	-270	1,908
NT Rice ($/ha)	802	560	70	-208	2,054
CT Soybean ($/ha)	338	342	101	-512	970
NT Soybean ($/ha)	385	282	73	-84	1,042
CT Rotation ($/ha)	578	404	70	-300	1,439
NT Rotation ($/ha)	593	385	65	-145	1,537

Notes: CT = conventional till; NT = no-till.
*Summary statistics calculated from 500 simulated iterations.
†Coefficient of variation (CV) is a unitless measure of relative risk and is equal to 100 multiplied by the quotient of the standard deviation divided by the mean.

Table 4
Net return certainty equivalents and no-till risk premiums for a rice-soybean rotation by crop, tillage, and rotation for various absolute risk aversion coefficients.

	Absolute Risk Aversion Coefficient						
Variable	0.0000	0.0011	0.0023	0.0034	0.0046	0.0057	0.0068
	Certainty Equivalent ($/ha)*						
CT Rice	818	633	471	347	257	190	141
NT Rice	802	626	471	350	261	195	146
CT Soybean	338	271	206	145	91	43	1
NT Soybean	385	342	305	273	246	223	204
CT Rotation	578	488	407	337	278	229	187
NT Rotation	593	512	439	375	320	274	236
	No-Till Risk Premium ($/ha)						
Rice	-16	-7	-1	2	4	5	6
Soybean	48	71	99	127	155	180	202
Rotation	16	24	32	38	42	46	49

Notes: CT = conventional till; NT = no-till.
*Certainty equivalents calculated assuming a negative exponential utility function.

Figure 1

Rice-soybean no-till risk premiums by crop and rotation over absolute risk aversion range of 0.0000 to 0.0068, assuming a negative exponential utility function.

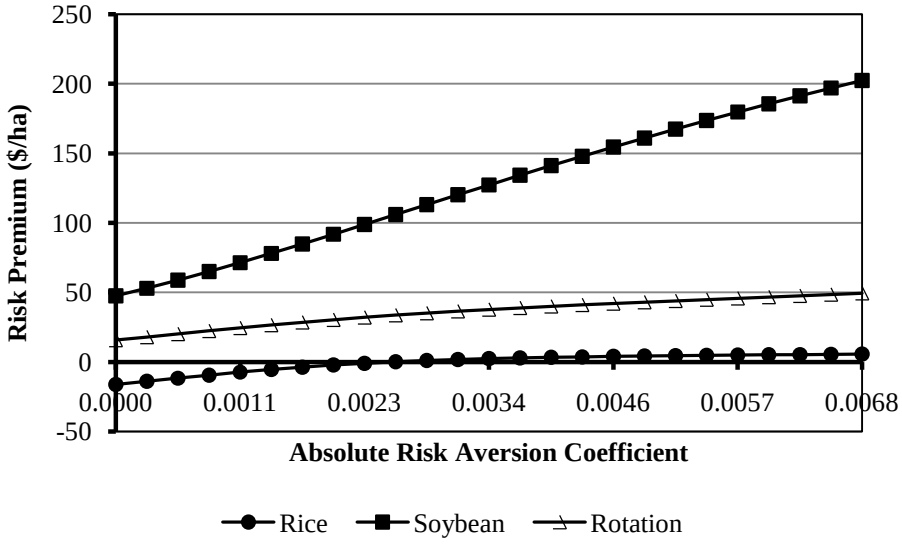

Figure 2

Stochastic efficiency with respect to a function results for rice net returns in a rice-soybean rotation over absolute risk aversion range of 0.0000 to 0.0068, assuming a negative exponential utility function.

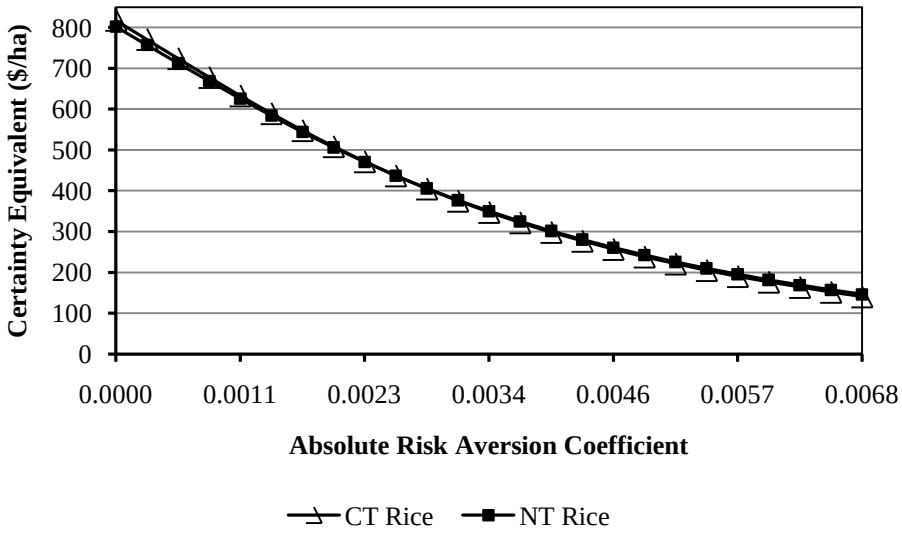

Figure 3

Stochastic efficiency with respect to a function results for soybean net returns in a rice-soybean rotation over absolute risk aversion range of 0.0000 to 0.0068, assuming a negative exponential utility function.

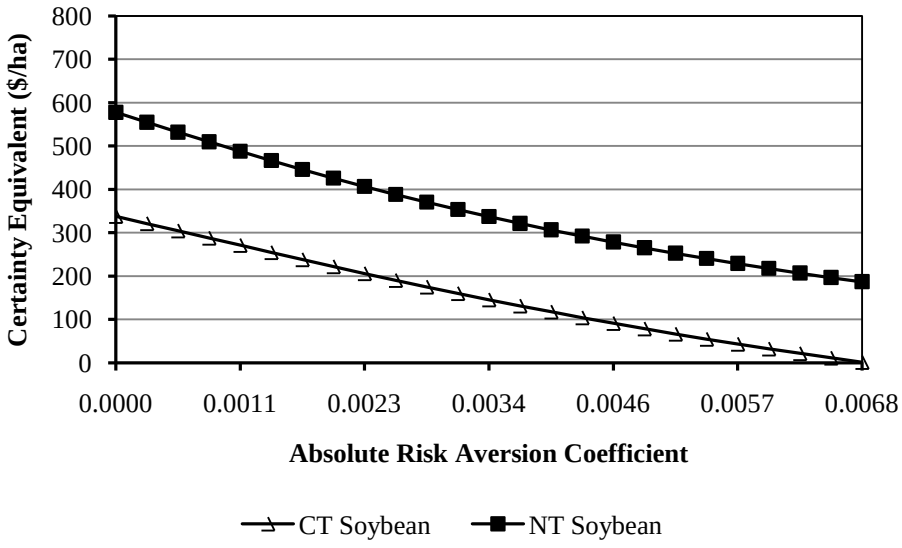

Figure 4

Stochastic efficiency with respect to a function results for rice-soybean rotation net returns over absolute risk aversion range of 0.0000 to 0.0068, assuming a negative exponential utility function.