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STAFF PAPER

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Double-Cropping Soybeans into
Traditional Crop Rotations Under
Government Commodity Program Restrictions

ABSTRACT

Six enterprise combinations, four including a double-crop sequence of wheat followed immediately after harvest by soybeans, are evaluated given the requirements for participation in the government commodity program. Stochastic dominance analysis is used to select the preferred combination under six different classes of risk preferences. A two-year sequence of wheat double-cropped with soybeans followed by full-season soybeans is the preferred combination for all classes of risk preferences analyzed. Sensitivity analysis indicates that if labor, machinery, or field time constraints limit the number of acres planted, results may favor enterprise combinations that do not include double-cropping or double-crop fewer than the maximum possible double-cropped acres.

Double-Cropping Soybeans into Traditional Crop Rotations Under Government Commodity Program Restrictions

Cropping sequence alternatives including double-cropping have recently received more attention at both the experiment plot and commercial field levels as possible income-enhancing and stabilizing strategies. However, the possibility of returns below those of single-cropping remains, because not much is known about the profitability of double-cropping in combination with other crop enterprises (Hexem and Boxley). Few economic analyses of double-cropping (the practice of planting a second crop immediately after harvesting the first) under government program restrictions appear in the literature. Agricultural commodity program payments can affect the variability and level of farm income and influence the selection of cropping sequences. However, program restrictions can also reduce the opportunity for changing cropping systems.

This study focuses on evaluating the net returns and risk of double-cropping soybeans after wheat in combination with other cropping alternatives under the government commodity program applicable to farming units in southeast Kansas.

CROP ENTERPRISES

Six alternative crop enterprise combinations that incorporate nine cropping sequences are analyzed in this study, four of which contain a sequence including double-crop soybeans after wheat. The typical southeast Kansas farm has base acres established in wheat and grain sorghum. The typical farm contains 600 acres of cropland (Langemeier; Langemeier and Parker) of which 194 acres are in wheat base and 107 acres are in feed grain (grain sorghum) base. In order to maintain base acres, it is assumed that farmers will plant the maximum number of acres of wheat and grain sorghum allowed under the government commodity program. Typically, the majority of land that is not devoted to these crops is planted to soybeans.

The six enterprise combinations considered possible under the government program restrictions given the available data are as follows:

1. W/DCSB, SOR-FSSB, CFSSB: 1) a one-year sequence of wheat and double-cropped soybeans, 2) a two-year rotated sequence of sorghum and full-season soybeans, and 3) continuous full-season soybeans.

2. W/DCSB-FSSB, SOR-FSSB: 1) a two-year sequence of wheat and double-cropped soybeans and full-season soybeans, and 2) a two-year rotated sequence of sorghum and full-season soybeans.

3. W-W-FSSB, SOR-FSSB, CFSSB: 1) a three-year rotated sequence of wheat-wheat and full-season soybeans, 2) a two-year rotated sequence of sorghum and full-season soybeans, and 3) continuous full-season soybeans.

4. W-W/DCSB-FSSB, SOR-FSSB, CFSSB: 1) a three-year rotated sequence of wheat, wheat and double-cropped soybeans and full-season soybeans, 2) a two-year rotated sequence of sorghum and full-season soybeans, and 3) continuous full-season soybeans.

5. W/DCSB-FSSB, SOR-FSSB-W/DCSB, CFSSB: 1) a two-year rotated sequence of wheat and double-cropped soybeans and full-season soybeans, 2) a three-year rotated sequence of sorghum, full-season soybeans and wheat and double-cropped soybeans, and 3) continuous full-season soybeans.

6. SOR-FSSB-W, W-FSSB, CFSSB: 1) a three-year rotated sequence of sorghum, full-season soybeans and wheat, 2) a two-year rotated sequence of wheat and full-season soybeans, and 3) continuous full-season soybeans.

The number of acres (before set-aside requirements) in each of the possible nine crop sequences for each of the six enterprise combinations are listed in Table 1. Combinations 1, 2, 4 and 5 each contain a double-cropped sequence. Crop sequences a, b, c, and d are part of an on-going double-cropping study being conducted at the Southeast Branch Experiment Station in Parsons, KS (Kelley). Crop sequences e, f, g, h, and i are commonly used in southeastern Kansas.

PROCEDURES

A distribution of potential net returns to land and management for each enterprise combination is calculated using yield and deflated southeast Kansas crop price data from 1982 to 1988, 1988 costs and requirements specified by the Food Security Act of 1985 for the 1989 crop year. Stochastic dominance analysis is used to select the risk-efficient cropping strategies.

Stochastic dominance uses risk preference intervals determined with the Pratt absolute risk aversion function, R(x). This function, defined by Pratt as $R(x) = -U''(x)/U'(x)$, represents the ratio of derivatives from the decision maker's utility function, U(x). First degree stochastic dominance (FDSD) rules identify strategies preferred by the individual whose utility is a positive function of income. The criteria are consistent for individuals who prefer more income to less. Second-degree stochastic dominance (SDSD) criteria identify strategies preferred by individuals receiving greater satisfaction from increases at low levels of income than increases at high levels of income. For FDSD, the interval is $R_1(x) = -\infty$ and $R_2(x) = +\infty$, and the interval for SDSD is $R_1(x) = 0$ and $R_2(x) = +\infty$.

Stochastic dominance with respect to a function (SDRF) analysis is used as well because it considers specific risk aversion preferences. The risk preference intervals bounded by lower and upper risk aversion coefficients, $R_1(x)$ and $R_2(x)$, are established by the researcher. Six risk preference intervals are used for the SDRF analysis. These intervals are assigned within the range suggested by King and Robison.

DATA FOR NET RETURN DISTRIBUTIONS

Crop Yields

Yield data for wheat, full-season soybeans (maturity group V), and double-cropped soybeans (maturity groups III and IV) were obtained from an ongoing study at the Southeast Kansas Branch Experiment Station on the yield effects of alternative cropping sequences (Kelley).

Average wheat yields by rotation are very similar, ranging from 31.6-32.8 bu/acre with coefficients of variation ranging from 94-99%. A substantial amount of variability occurs in wheat yield from year to year in this area of the state. Average full-season soybean yields range from 23.3 bu/acre to 25.1

bu/acre with coefficients of variation ranging from 37-40%. Average yields for double-crop soybeans are lower and range from 17.0 - 17.9 bu/acre but have about the same level of variability as full-season soybeans. The lower yields result in coefficients of variation ranging from 56-57%. The average grain sorghum yield is 66.2 bu/acre with a coefficient of variation of 20%.

Variable and Fixed Costs

Variable costs include fuel, oil, repairs, labor, seed, fertilizer, herbicide, insecticide, and hauling. Seeding, nitrogen, phosphate, potash, herbicide, and insecticide rates are from experiment station practices and recommendations by experiment station personnel.

Fuel, lubrication, and machinery repair costs are based on typical field operation requirements. The machinery complement necessary to complete the field operations required for the most traditional southeast Kansas enterprise combination (combination 6) 70% of the time (Buller et al.) is determined using procedures outlined by Schrock. These procedures determined the equipment complement that a typical farmer would have. The machinery complement developed for this rotation is also capable of completing the other five combinations (combinations 1 - 5) for the acreages specified in Table 1.

Fixed costs on machinery include charges for depreciation, annual interest, insurance, and housing. Fixed costs are also adjusted to reflect the increased usage of machinery in the double-cropped rotations.

Net Returns

Procedures used for calculating each observation of annual net return to land and management for the distributions under the 1989 government program are described by equation (1).

$$(1)\ \sum_{i=1}^{3} NR_{in} = \sum_{i=1}^{3} \{[(\max\{P_{in}, EL_{iN}\} * Y_{in}) - VC_{iN} - FC_{iN}] * PA_{iN} - [MC_{iN} + FC_{iN}) * ARP_{iN}]\} + PAY_{in}\}$$

where:

$$PAY_{in} = \{DP_{in} * PA_{iN}\} * PY_{iN}$$

If $\sum_{i=1}^{3} PAY_{in} > \$50,000$ then:

$$\sum_{i=1}^{3} NR_{in} = \sum_{i=1}^{3} \{[(\max\{P_{in}, EL_{iN}\} * Y_{in}) - VC_{iN} - FC_{iN}] * PA_{iN} - [(MC_{iN} + FC_{iN}) * ARP_{iN}]\} + \$50,000 + \min\{\sum_{i=1}^{2} [(FL_{iN} - EL_{iN}) * PY_{iN} * PA_{iN}\}, \$200,000\}$$

Where:

i = 1-3 (1 = wheat, 2 = grain sorghum and 3 = soybeans)
n = 1,...,N (N = 7 years),
NR_{in} = net returns, crop i ($) for observation n,
P_{in} = market price, crop i ($/bu.), for observation n,
EL_{iN} = effective national average loan rate ($/bu.),
Y_{iN} = average yield on planted acreage (bu./acre),
VC_{iN} = variable costs of production ($/acre),
FC_{iN} = fixed costs ($/acre),
BA_{iN} = base acres, crop i,
ARR_{iN} = acreage reduction requirement (% of BA_i),
ARP_{iN} = acreage reduction program acres, where: $ARP_{iN} = ARR_{iN} * BA_{iN}$,
PA_{iN} = planted acres, crop i, where: $PA_{iN} = BA_{iN} - ARP_{iN}$
MC_{iN} = maintenance cost for diverted acres ($/acre),
PAY_{in} = government payments ($),
DP_{in} = deficiency payments ($/bu.), where: $DP_{in} = \max\{(TP_{iN} - \max\{P_{in}, EL_{iN}\}), 0\}$,
TP_{iN} = target price ($/bu.),
EP_{iN} = expected national average price ($/bu.),
PY_{iN} = program yield (bu./acre), and
FL_{iN} = formula loan rate ($/bu.).

Yields (Y_{in}) are assumed to be the same as the historical yield values. The yield is used to calculate the gross return on the crop actually produced. Market prices (P_{in}) are assumed to be the season average prices. When returns are calculated under the government program provisions, the market price is not allowed to fall below the effective loan rate (EL_{iN}). This is the lowest effective price a manager could receive if participating in the program. The commodity programs encompass wheat and grain sorghum (among other crops), but do not include soybeans with the exception of a loan rate that is substantially below any market price used in the analysis. Thus, net returns for soybeans are unaffected by the loan rate. In Equation (1), set-aside acres for soybeans (ARR_{3n}) are zero, and net returns are calculated as before by multiplying yield (Y_{3n}) by price (P_{3n}) and subtracting costs (VC_{3n} and FC_{3n}), then multiplying by the total acres planted (PA_{3n}). Deficiency payments per bushel (DP_{iN}) are determined by subtracting the greater of the market price or the effective loan rate from the target price. Total deficiency payments are found by multiplying this value by program yield (PY_{iN}) and planted acres (PA_{iN}).

ANALYSIS AND RESULTS

The distributions of net returns under the government commodity program conditions are listed in Table 2. Enterprise combination 2, which includes 388 acres of the two-year rotated sequence of wheat double-cropped with soybeans and full-season soybeans (194 acres each year), has the highest average net return and the highest standard deviation but has the lowest relative variability as measured by the coefficient of variation. Combination 6, which is a traditional enterprise combination containing a sequence of grain sorghum, full-season soybeans, and wheat, has the lowest variability as measured by the standard deviation but the next to the lowest net return.

Stochastic Dominance

Stochastic dominance analysis is conducted to determine which enterprise combinations are preferred for farmers having different risk preferences (Table 3). FDSD is the least discriminating procedure (in that it considers all risk classes, i.e., all managers interested in higher net returns regardless of risk preferences), eliminating only combination 5 from the preferred set. SDSD is slightly more discriminating than FDSD (it considers only risk neutral and risk averse decision makers), eliminating combination 1 as well as combination 5 from the preferred set. Combination 1 has the largest single-year loss of any of the rotations.

SDRF allows for the consideration of specific risk classes. Combination 2 is preferred by all risk classes analyzed (Table 3). This combination has the highest average net return and the lowest relative risk as measured by the coefficient of variation (Table 2). The fact that this rotation has the maximum number of acres possible in double-crop soybeans and no acres in continuous full-season soybeans is particularly important in generating the high average net returns to land and management.

Sensitivity Analysis

Because the yield data for the double-crop rotations are obtained from experimental plot rotations and are extrapolated to larger acreages (commercial fields) for this analysis, they must be viewed with caution. Double-cropping requires a high degree of management expertise and favorable weather and soil conditions to be successful. It involves harvesting the first crop and planting the second crop within a short time period, which is less difficult to complete on small experimental plots. However, a farm manager would have more difficulty completing all field operations every year. Planting of double-crop soybeans must follow wheat harvest as quickly as possible. In addition, harvest for both full-season and double-crop soybeans coincides with wheat field preparation and planting in this area. Because custom combining is generally not available in southeast Kansas, an operator would need an adequate amount of machinery, qualified labor, and field time to handle these competing enterprises. On many farms, constraints on these resources could possibly limit the number of double-crop soybean acres grown.

Because of these concerns, sensitivity analysis is conducted to determine the magnitude of a parallel shift of the dominant distribution (combination 2) required to eliminate its dominance and produce an efficient set containing both the previously dominant distribution (combination 2) and the specified alternatives (Table 4). The dollar value of this shift is shown in column 4. The minimum number of double-crop acres required to meet this shift is listed in column 5. The equivalent reduction in the double-crop yield required to make the combinations without any double-cropping (combinations 3 and 6) part of the efficient set with combination 2 can be found in column 6.

Using the moderately risk-averse interval as an example (Table 4), if the enterprise combination 2 distribution is lowered by a parallel shift of $291, combination 1 (which is quite similar to combination 2) enters the efficient set. Conversely, combination 3 (a three-year wheat rotation of wheat, wheat, and full-season soybeans with no double-cropping) requires a shift of $4,771 to enter the efficient set. For combination 3, this is equivalent to being able to only plant 110.5 acres of double-crop soybeans (out of a maximum of 194 acres) in enterprise combination 2 or reducing the double-crop soybean yield by 3.9 bushels/acre (23% yield reduction).

The results of this sensitivity analysis indicate that if less than the maximum acres of double-crop soybeans can be planted and/or commercial field yields are less than experiment station yields, then the dominance of enterprise combination 2, which contains a large amount of double-cropped soybeans, is in question. In certain cases, only modest decreases in the number of acres planted or in yield would lead to the dominance of combinations containing less than the maximum number of double-crop soybean acres. For example, the reduction of combination 2's double-crop acres by fewer than 10 acres (5% acreage reduction) or a decrease in yield of one-half bushel per acre (3% yield reduction) would lead to the traditional combination 6 being included in the efficient set for the class of strongly risk-averse producers.

SUMMARY AND CONCLUSIONS

This study analyzes the economic returns and risk associated with crop enterprise combinations of wheat, full-season soybeans, grain sorghum, and double-cropped soybeans in southeastern Kansas. Six enterprise combinations (four of which include a crop sequence of wheat followed by double-cropped soybeans) are evaluated considering the requirements for participating in the government commodity program.

Stochastic dominance analysis indicates that managers would prefer a two-year sequence of wheat and double-cropped soybeans followed by full-season soybeans, regardless of risk preference. The amount of acreage that must be planted after wheat harvest without significant double-crop soybean failure is an important factor in this result. Sensitivity analysis indicates that if labor, machinery, or field time constraints limit the number of acres of double-cropped soybeans and/or farm yields are sufficiently less than those included in the data set, results would favor rotations that do not double-crop or double-crop less than the maximum number of acres each year.

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Table 1. Alternative Crop Enterprise Combinations Analyzed for Southeastern Kansas.

Crop Sequence	Enterprise Combination 1	2	3	4	5	6
	--------------number of acres*------------					
a) W/DCSB	194					
b) W/DCSB-FSSB		388			174	
c) W-W-FSSB			291			
d) W-W/DCSB-FSSB				291		
e) SOR-FSSB-W/DCSB					321	
f) SOR-FSSB-W						321
g) SOR-FSSB	214	212	214	214		
h) W-FSSB						174
i) CFSSB	192		95	95	105	105
Wheat + Set-aside	194	194	194	194	194	194
Grain Sorghum + Set-aside	107	107	107	107	107	107
Soybeans						
FSSB	107	301	204	204	194	194
CFSSB	192	0	95	95	105	105
DCSB	194	194	0	97	194	0
Single-Cropped (x1)	406	406	600	503	406	600
Double-Cropped (x2)	194	194	0	97	194	0
Total	794	794	600	697	794	600

*Number of acres before set-aside.

a) W/DCSB: a one-year sequence of wheat and double-cropped soybeans (194 acres).
b) W/DCSB-FSSB: a two-year sequence of 1) wheat and double-cropped soybeans and 2) full-season soybeans. Soybeans are planted on half of the acreage in rotation each year and half of the acreage is used for W/DCSB and setaside each year.
c) W-W-FSSB: a three-year sequence of 1) wheat (97 acres), 2) wheat (97 acres), and 3) full-season soybeans (97 acres).
d) W-W/DCSB-FSSB: a three-year sequence of 1) wheat (97 acres), 2) wheat and double-cropped soybeans (97 acres), and 3) full-season soybeans (97 acres).
e) SOR-FSSB-W/DCSB: a three-year sequence of 1) sorghum (107 acres), 2) full-season soybeans (107 acres), and 3) wheat and double-cropped soybeans (107 acres).
f) SOR-FSSB-W: a three-year sequence of 1) sorghum (107 acres), 2) full-season soybeans (107 acres), and 3) wheat (107 acres).
g) SOR-FSSB: a two-year sequence of 1) sorghum and 2) full-season soybeans. Soybeans are planted half of the acreage in rotation each year and half of the acreage are used for grain sorghum and set-aside each year.
h) W-FSSB: a two-year sequence of 1) wheat (87 acres) and 2) full-season soybeans (87 acres).
i) CFSSB: continuous full-season soybeans planted on the same land year after year.

Table 2. Net Return to Land and Management Distributions for Alternative Crop Enterprise Combinations.

	Enterprise Combination*					
	1	2	3	4	5	6
	$37,506	$35,396	$19,257	$25,149	$32,917	$21,146
	27,538	30,326	11,758	19,119	27,488	13,782
	-12,974	-11,035	-1,820	-8,262	-12,428	-62
	21,278	23,309	-803	9,406	20,171	202
	-3,549	-5,441	-11,446	-10,319	-7,149	-10,346
	29,377	28,221	22,320	22,457	26,780	23,222
	46,094	48,002	52,954	50,672	45,867	49,192
Mean	$20,753	$21,254	$13,174	$15,460	$19,092	$13,891
Std. Dev.	$21,493	$21,625	$21,336	$21,056	$21,295	$19,802
Coef. Var.	1.04	1.02	1.62	1.36	1.12	1.43
Minimum	-12,974	-11,035	-11,446	-10,319	-12,428	-10,346
Maximum	46,094	48,002	52,954	50,672	45,867	49,192

*Please refer to Table 1 or the text for a complete description of the crop enterprise combinations.

Table 3. Stochastic Dominance Analysis Results.

Approximate Risk Attitude	Range of Pratt-Arrow Risk Aversion Coefficients	Dominant Crop Enterprise Combinations*
FDSD:		
All risk classes	$-\infty$ to $+\infty$	1-4, 6
SDSD:		
Risk neutral and risk averse	0 to $+\infty$	2, 4, 6
SDRF:		
Moderately risk preferring	-.00005 to -.00001	2
Slightly risk preferring	-.00001 to 0.0	2
Risk neutral	-.00001 to +.00001	2
Slightly risk averse	0.0 to +.00001	2
Moderately risk averse	+.00001 to +.00005	2
Strongly risk averse	+.00005 to +.0001	2

*Please refer to Table 1 or the text for a complete description of the crop enterprise combinations.

Table 4. Sensitivity Analysis for Stochastic Dominance Results.

Risk Category	Dominant Combination[a]	Compared Combination[a]	Decrease in Net Return of Dominant Combination[b]	Minimum Acres of DCSB[c]	Bushels Per Acre DCSB[d]
Moderately Risk Preferring	2	1	$ 428	186.5	---
		5	2,206	155.4	---
		4	3,802	127.5	---
		3	4,288	98.0	4.5
		6	5,483	118.9	3.5
Slightly Risk Preferring	2	1	472	185.7	---
		5	2,161	156.2	---
		4	5,508	97.6	---
		6	7,075	70.2	5.8
		3	7,551	61.8	6.2
Risk Neutral	2	1	413	186.8	---
		5	2,094	157.3	---
		4	5,163	103.6	---
		6	6,504	80.2	5.3
		3	7,073	70.2	5.8
Slightly Risk Averse	2	1	446	186.2	---
		5	2,094	157.3	---
		4	5,399	99.5	---
		6	6,730	76.2	5.5
		3	7,516	62.4	6.2
Moderately Risk Averse	2	1	291	188.9	---
		5	1,777	162.9	---
		4	3,451	133.6	---
		6	3,601	131.0	2.9
		3	4,771	110.5	3.9
Strongly Risk Averse	2	1	415	186.7	---
		6	561	184.2	0.5
		4	1,556	166.8	---
		5	1,563	166.6	---
		3	1,838	161.8	1.5

[a]For identification of crop rotations, please refer to Table 1 or the text.

[b]The decrease in net return is the magnitude of the parallel shift of the dominant distribution (combination) that is necessary to eliminate its dominance over the indicated combination. The average net return of combination 2 is $21,254.

[c]The minimum number of acres of double-crop soybeans that would have to be planted each year of a possible 194 acres for the dominant combination to remain dominant to the indicated combination. The DCSB yield used is the seven-year average from combination 2 of 17.0 bu/acre. Variable costs for DCSB in combination 2 are $50.14/acre.

[d]The decrease in DCSB bushels per acre is the amount of yield decrease in the dominant distribution necessary to eliminate its dominance over the indicated combination. The price used is the seven-year average soybean price of $6.31/bu. These decreases in yield are only listed when the dominant combination is compared with combinations that do not include a double-cropped soybean sequence (Combinations 3 and 6).