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Ranking Specialty Crop Profitability: Iterative Stochastic Dominance

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This research used stochastic dominance with respect to a function to evaluate producer preference for cropping systems under uncertainty. Six alternative cropping systems were compared for seven different crops. Many times a producer is familiar a developing market opportunity for a specialty crop and the producer has to make a production decision based on yield uncertainty. This research analyzed by how much alternative crop and bio-energy crop yields would need to change to make a producer indifferent between the most preferred (dominant) cropping system and an alternative cropping system. For the current study, the stochastic dominance results indicate that the change in yield necessary is sufficiently large enough to keep producers from accepting the risk of engaging in alternative crop or bio-energy crop production. The paper concludes with study limitations, which the reader is encouraged to review.

Keywords: Risk, Specialty Crops, Agronomic Alternative Crops

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Demand for bio-energy crops and alternative crops is experiencing significant growth and creating renewed interest in diversified crop production, including the use of cover crops for conservation and sustainability. One major limiting factor to adoption of more diversified cropping systems has been a lack of good information and guidance on the agronomic and economic aspects of producing non-traditional crops.

Agricultural production is currently characterized by a lack of crop diversity in many regions of the United States. In 2010, three major grain crops (corn, soybeans, and wheat) occupied 85% of the land devoted to all row crops in the United States (USDA, 2010). This lack of diversity means many fields have the same crop grown year after year, and many farmers rely on one or two crops, regardless of market prices or growing conditions. Agricultural producers face many obstacles when adopting new cropping practices. The driving force behind adoption of these crops is twofold: the market price and yield. Prior economic analysis evaluating specialty crop production has focused on price (e.g., Delbridge et al). For example, a producer might dabble into sunflower production because there is a local market developing for sunflowers (sometimes under contract prices). These producers are then faced with the reality of undertaking in specialty crop production without known yield history. The research question here is, at what level of yield is necessary for producers to be as financially well-off, or indifferent based on the producers risk level, between producing specialty crops and producing conventional crops, i.e., corn and soybean? We answer this question by iterative stochastic dominance of replacing specialty crop yield in a cost-return budget.

Previous Research

It has been reported in a number of studies that crop diversification offers many potential economic and environmental benefits for producers. A national report addressing this issue was "Diversifying U.S. Crop Production," produced by the Council for Agricultural Science and Technology (Janick, et al., 1996). This report identified several benefits to diversifying cropping systems with new crops, including increased yields and profits in rotated crops, reduced pest pressure, increased erosion control, and reduced risk from extremes in weather conditions or market prices. Several studies have provided evidence that crop diversification can lead to reduced input costs and lower pest populations. A study by Moroke et al. (2005) indicates crop rotation using different species allows stratified use of soil water, thereby reducing both depletion of water in a given root zone and the corresponding need for irrigation during a season. A separate study by Miller et al. (2006) found that of 16 rotational crops evaluated for ability to reduce soybean cyst nematode (SCN) populations following susceptible soybean, all reduced SCN populations, with corn being the least effective. Thus, SCN populations could be greater reduced using a diverse rotation versus a corn-soybean rotation. A third study found that the inclusion of faba bean or chickpea in a two-year rotation contributed to improved water use efficiency of wheat (Lopez-Bellido et al., 2007).

In addition to reducing input costs and pest populations, crop diversification can reduce weed pressure. Results of a literature survey by Liebman and Dyck (1993) indicated crop rotation reduced weed population density and biomass production in comparison to a monoculture system. According to the authors, “The success of rotation systems for weed suppression appears to be based on the use of crop sequences that create varying patterns of resource competition, allelopathic interference, soil disturbance, and mechanical damage to provide an unstable and frequently inhospitable environment that prevents proliferation of a particular weed species." Reduced weed pressure could reduce herbicide applications and cost, leading to improved profitability and water quality.

Agricultural producers wishing to increase profitability are often able to create or capture value of their production through processing and marketing. As small and mid-size farm operations seek to maintain or increase profitability, they are attempting to increase their share of the food dollar through activities such as direct marketing to consumers, on-farm processing, and membership in producer cooperatives that invest in larger scale facilities targeting value-added processing. Purdue University research indicates producers may benefit from diversifying into a value-added business related to the producer's product when the product is characterized by volatile prices at the farm gate and relatively stable prices at the wholesale or retail level (Fulton, 2003).

Diversifying the number of crops on the farm, particularly for different markets, such as food, feed, and bioenergy uses, can help offset fluctuations in market price for a given commodity area. For example, a corn and soybean producer would find the market for both crops closely tied to the demand for livestock feed, while the price of a food crop (such as amaranth) or an industrial oilseed (such as camelina) might be unaffected. New crops with potential for bioenergy or other industrial uses can broaden the marketplace for crop use, because they can serve as a source of renewable resources, typically substituting for nonrenewable petroleum-based products (Johnson, 2000). Individual producers can sometimes obtain higher profit potential for a new crop compared to a traditional crop, particularly if direct marketing is involved (current examples of this include quinoa and amaranth).

Diversification into alternative biomass crops and other bioenergy crops is a major new development for Midwest farmers. Recently, there has been considerable attention given to biomass to renewable energy projects where farm-producers raise biomass crops and sell into the renewable energy company.

Alternative Crop Returns Data and Budget

The economic analysis is for a typical Missouri crop farmer outside of the Mississippi delta region. Agronomic specialty crop and bio-energy crop cost-return budgets were developed for Missouri through expert opinion as a component of a USDA AFRI grant. Corn and soybean cost-return data is based on FAPRI baseline projections for the next three years. The FAPRI baseline corn and soybean yield is adjusted to reflect a Missouri crop farmer. Summary statistics are detailed in Table 1. The cropping systems modeled for this analysis are in Table 2.

Sunflower, winter canola, sweet sorghum, corn, and soybean are annuals. Price, yield, and variable cost data were collected for the next six production years starting with 2014. FAPRI baseline data includes price, yield, and variable cost data for corn and soybean. We used prices for sunflower from FAPRI baseline projection data. Sunflower variable cost was derived from expert opinion, and this price was adjusted by the same rate that corn input costs are expected to increase in the FAPRI baseline data.

Sweet sorghum yield data and variable cost data was estimated from expert opinion. Sweet sorghum yield is held fixed at 28 tons/acre for any of the next six years. Sweet sorghum variable cost was inflated at the same rate of corn in the FAPRI baseline data. Sweet sorghum price is difficult to obtain. We used a value of $17.34/ton and then allowed the price to change at the same change as corn price is expected to change in the FAPRI baseline data.

Canola yield and variable cost data is based on expert opinion. Canola yield is allowed to increase at the same rate of soybean yield in the FAPRI baseline data. Canola harvested seed price is correlated with the soybean price, due to meal and oil use, so the canola price changes at 90% of the soybean price change in the FAPRI baseline data. We do not consider double-cropping for winter canola.

Miscanthus and switchgrass price, yield, and variable cost are based on expert opinion. The price, for either bio-energy crops, is projected to vary similar to hay price over the next six years. These two crops include government subsidies for one-half of establishment costs in year one for both miscanthus and switchgrass, one-half of maintenance cost in year two for switchgrass, and annual production incentives in years three through five. Variable cost change as the same rate as the average cost of inputs for conventional crops from the FAPRI baseline.

Yield per acre for miscanthus is: 0 ton in year 1, 5 ton in year 2, and 10 ton in each of year 3 through 6. Yield per acre for switchgrass is: 0 in year 1, 3 ton in year 2, and 6 ton in each of year 3 through 6. For both bio-energy crops, we allow the yield in years 3 through 6 to be randomly determined, as explained later. Yield per acre for sweet sorghum is 28 ton each year. Yield for the other four crops are randomly drawn using a truncated normal distribution from the six year yield projections described above.

Prices for each of the seven crops analyzed were randomly selected, using a normal distribution, from the six year price projections described above. Variable costs for the crops other than miscanthus and switchgrass were randomly selected, using a normal distribution, from the six year price projections described above. For miscanthus and switchgrass expert opinion was used in years 1 and 2 for establishment costs and then for the final four years costs were randomly drawn following a normal distribution.

The economics of the cropping systems, as listed in Table 2, do not account for yield or cost differences based on the crop rotation. That is, if soybean is in the first crop in the rotation for sunflower and canola, then the soybean price, yield, and variable cost is the same in both cropping system. And, the soybean price, yield, and variable cost values will be the same in year 3 between these two cropping systems.

Procedures

Stochastic dominance with respect to a function can be used to compare net return distributions for various alternatives (King and Robison). This technique is particularly useful when making pair-wise comparisons between mutually exclusive alternatives. To use stochastic dominance with respect to a function, information on risk attitudes is needed. Raskin and Cochran discuss the importance of adjusting risk-aversion coefficients when the scale of the outcome variable used is different than that of the study for which risk attitudes are elicited. Using elicited measures of farmer risk aversion from King and Robinson and certainty equivalent risk aversion levels from Kramer and Pope, Raskin and Cochran's methodology is used to transform risk attitudes as follows:

$$c = x/w \qquad (1)$$

and

$$r(w) = cr(x), \qquad (2)$$

where *w* represents profits per acre for a specific specialty crop, *x* represents the level of income used in King and Robinson, *r(w)* represents the transformed risk-aversion coefficients, *r(x)* represents the risk-aversion coefficients used in King and Robinson and Kramer and Pope, and c is a constant determined in equation 1.

Estimated profits per acre, for conventional and specialty crops, are used to evaluate the pair-wise dominance of six cropping alternatives. Risk-aversion levels used for this analysis included risk neutral (-0.0015) to moderately risk-averse (0.015).[1] The following steps are used to determine the yield level at which a producer would prefer a specialty crop cropping system to a conventional crop cropping system:

Step 1. List distribution and specify a risk-aversion interval. For conventional crop production returns to land and management per acre is denoted by:

$$w_t^C \quad = Returns\ to\ land\ and\ management_t / acre_t \quad for\ t = years = 1, \ldots, 6$$

For selected specialty crop production the returns to land and management per acre is denoted by:

$$w_t^S \quad = (base\ yield_t \times (price/unit)_t) - variable\ cost_t \quad for\ t = years = 1, \ldots, 6$$

where base yield is a specialty crop yield expected based on expert opinion.

Step 2. Increase each computed specialty crop yield (starting at base yield) in each year for the selected crop in intervals of 1% above base yield.

[1] Following the original analysis with these chosen risk aversion coefficients, stochastic efficiency analysis was conducted to find whether cropping system switching exist over a range of risk aversion levels. The switching of ordering was most pronounced between -1 (strongly risk preferring) and +1 (strongly risk averse). A secondary analysis is reported for this larger range of risk aversion levels.

Step 3. Continue iterating until returns to land management for the selected specialty crop are at a certainty equivalent level to conventional crop returns to land and management, for the given risk-aversion interval. This is the necessary parity yield making producers indifferent between conventional crop production and specialty crop production.

A similar process can then be used for each alternative cropping system. The agronomic specialty crops to be examined include sunflowers, winter canola, biomass (sweet) sorghum, switchgrass, and miscanthus.

Because bio-energy crops, i.e., miscanthus and switchgrass here, require an establishment period, it was necessary to conduct a multi-year financial comparison between the alternative cropping systems (as shown in Table 2). Thus, the returns to management and land are computed as a six-year net present value using an eight percent discount factor.[2] Then, using Simetar® one hundred simulations of the data were generated for ranking and analyzing producer cropping system preferences as the risk level changes. The simulations are drawn from the distributions specified above for price, yield, and variable costs.

Empirical Results and Considerations

Two separate sets of results are presented in Tables 3 and 4 and in Tables 5 and 6. The later tables report results from a much larger range of risk aversion, which the risk levels were chosen based on analyzing a range of certainty equivalent values using the stochastic efficiency methodology. Simetar® was used for analyzing stochastic dominance and for computing certainty equivalence from the stochastic efficiency frontier.

Tables 3 is used to indicate the rankings of preferred cropping systems at the risk neutral level (-0.0015) and risk averse scenario (0.015). At both risk aversion levels the soybean and

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[2]The final results of this research were not found to be sensitive to the choice of discount rate.

sweet sorghum cropping system was the most preferred of the six cropping systems compared. The traditional corn and soybean cropping system was the second most preferred cropping system of the six cropping systems compared. Table 4 is used to indicate the confidence premiums and the production (annual for the alternative crop is produced) necessary to induce a change in cropping system, relative to the most preferred cropping system. For the corn and soybean cropping system of the lower bound (-0.0015), the stochastic dominance analysis shows that the corn yield would need to increase by 0.15 bushel/acre to make the risk neutral producer indifferent between a corn and soybean rotation and a soybean and sweet sorghum rotation. Because corn is only cropped in three of the six years, the 0.15/bushel/acre yield increase is only needed in years one, three, and five. For the upper bound, a risk averse producer would require a 0.34 bushel/acre corn yield increase to be indifferent between the corn and soybean rotation and a soybean and sweet sorghum rotation. The yield difference is negligible. However, if the cropping system was only miscanthus, then a 4.75 ton/acre increase (or about 50% of full productivity mean) in yield would be necessary to make a producer indifferent between growing miscanthus and growing a soybean and sweet sorghum rotation.

Tables 4 is used to indicate the rankings of preferred cropping systems at the risk preferring level (-1) and a strongly risk averse level (+1). The traditional corn and soybean cropping system was the most preferred cropping system, of the six cropping systems compared, for the risk preferring producer. A soybean and canola cropping rotation was the most preferred cropping system, of the six cropping systems compared, for the strongly risk averse producer. Table 4 is used to indicate the confidence premiums and the production (annual for the alternative crop is produced) necessary to induce a change in cropping system, relative to the most preferred cropping system. For the soybean and sweet sorghum cropping system of the lower bound (-1), the stochastic dominance analysis shows that the sweet sorghum yield would need to increase by 0.37 ton/acre to make the risk preferring producer indifferent between a corn and soybean rotation and a soybean and sweet sorghum rotation. Note, the 0.37 ton/acre necessary to induce a change would only be necessary in years two, four, and six of the six year cropping rotation. For the upper bound (+1), a risk averse producer would accept a 0.25 bushel/acre corn yield decrease to be indifferent between the corn and soybean rotation and a soybean and sweet sorghum rotation. The yield difference is negligible. However, if the cropping system was only miscanthus, then a 5.18 to 5.5 ton/acre increase (or 50% of full productivity mean) in yield would be necessary to make a producer indifferent between growing miscanthus and the most dominant distribution cropping system.

Considerations

This research used stochastic dominance with respect to a function to evaluate producer preference for cropping systems under uncertainty. Six alternative cropping systems were compared for seven different crops. Many times a producer is familiar a developing market opportunity for a specialty crop and the producer has to make a production decision based on yield uncertainty. This research analyzed by how much alternative crop and bio-energy crop yields would need to change to make a producer indifferent between the most preferred (dominant) cropping system and an alternative cropping system. For the current study, the stochastic dominance results indicate that the change in yield necessary is sufficiently large enough to keep producers from accepting the risk of engaging in alternative crop or bio-energy crop production.

This study lacks in many areas. Additional cropping systems should be considered, such as continuous corn or continuous soybean. The later rotation is common in Missouri. Also, wheat double cropped with soybean could be considered. The research also needs a refinement of price, yield, and variable costs for each of the alternative crops. Using in-field studies of yield expectations (base yield) will contribute to a more refined analysis. Prices for alternative crops are difficult to know until a local market emerges. More data is needed on prices and the variation of prices.

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Table 1. Summary Statistics

	Average	Standard Deviation	Minimum Value	Maximum Value
Corn				
Price	4.08	0.05	4.02	4.17
Yield	168.68	3.81	163.50	173.70
Variable Costs	339.00	5.11	333.37	347.08
Soybean				
Price	9.77	0.08	9.68	9.85
Yield	45.80	0.87	44.60	46.90
Variable Costs	155.83	3.32	152.73	161.16
Canola				
Price	0.25	0.00	0.25	0.25
Yield	2224.65	20.02	2200.00	2251.20
Variable Costs	285.31	4.30	280.57	292.11
Sunflower				
Price	0.18	0.00	0.18	0.18
Yield	1564.33	14.08	1547.00	1583.00
Variable Costs	298.88	4.50	293.91	306.00
Miscanthus				
Price	48.24	1.07	47.13	50.00
Yield	7.50	4.18	0.00	10.00
Variable Costs	519.99	228.70	407.17	978.85
Switchgrass				
Price	48.24	1.07	47.13	50.00
Yield	4.50	2.51	0.00	6.00
Variable Costs	228.59	51.80	143.78	261.02
Sweet Sorghum				
Price	17.92	0.43	17.56	18.73
Yield	28.00	0.00	28.00	28.00
Variable Costs	234.92	3.54	231.02	240.52

Table 2. Cropping Systems Used for Analysis

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Corn	Soybean	Corn	Soybean	Corn	Soybean
Soybean	Canola	Soybean	Canola	Soybean	Canola
Soybean	Sunflower	Soybean	Sunflower	Soybean	Sunflower
Switchgrass	Switchgrass	Switchgrass	Switchgrass	Switchgrass	Switchgrass
Miscanthus	Miscanthus	Miscanthus	Miscanthus	Miscanthus	Miscanthus
Soybean	Sweet Sorghum	Soybean	Sweet Sorghum	Soybean	Sweet Sorghum

Table 3. Efficient Set Based on Chosen Risk Aversion Coefficient

Efficient Set Based on SDRF at Lower RAC	**-0.0015**	Efficient Set Based on SDRF at Upper RAC	**0.015**
Name	Level of Preference	Name	Level of Preference
Soy - SS	Most Preferred	Soy – SS	Most Preferred
Corn – Soy	2nd Most Preferred	Corn - Soy	2nd Most Preferred
Soy - Canola	3rd Most Preferred	Soy - Canola	3rd Most Preferred
Soy - Sun	4th Most Preferred	Soy – Sun	4th Most Preferred
Miscanthus	5th Most Preferred	Miscanthus	5th Most Preferred
Switchgrass	Least Preferred	Switchgrass	Least Preferred

Table 4. Confidence Premiums Between Probability Distributions

	Lower Bound		Upper Bound	
Dominant Series	Absolute Amount	Annual Production Increase Necessary	Absolute Amount	Annual Production Increase Necessary
Soy - SS	The Most Dominant Distribution			
Corn – Soy	1.94	0.15 bu	4.21	0.34 bu
Soy - Canola	9.14	12.25 bu	7.63	10.23 bu
Soy-Sun	641.00	1185 lbs	639.47	1183 lbs
Miscanthus	917.02	4.75 tons	917.87	4.75 tons
Switchgrass	1,040.19	5.39 tons	1,050.42	5.44 tons

Table 5. Efficient Set Based on Chosen Risk Aversion Coefficient

Efficient Set Based on SDRF at Lower RAC	**-1**	Efficient Set Based on SDRF at Upper RAC	**1**
Name	Level of Preference	Name	Level of Preference
Corn - Soy	Most Preferred	Soy - Canola	Most Preferred
Soy - SS	2nd Most Preferred	Soy – SS	2nd Most Preferred
Soy - Canola	3rd Most Preferred	Corn – Soy	3rd Most Preferred
Soy - Sun	4th Most Preferred	Soy-Sun	4th Most Preferred
Miscanthus	5th Most Preferred	Miscanthus	5th Most Preferred
Switchgrass	Least Preferred	Switchgrass	Least Preferred

Table 6. Confidence Premiums Between Probability Distributions

	Lower Bound		Upper Bound	
Dominant Series	Absolute Amount	Annual Production Increase Necessary	Absolute Amount	Annual Production Increase Necessary
Corn - Soy	The Most Dominant Distribution			
Soy – SS	20.54	0.37 ton	-13.21	-0.25 ton
Soy - Canola	43.39	58.23 bu	-16.90	-22.7 bu
Soy - Sun	679.09	1256 lbs	613.34	1135 lbs
Miscanthus	926.55	4.8 tons	897.83	4.65 tons
Switchgrass	1,000.12	5.18 tons	1,079.58	5.59 tons