Economics of Crop Diversification Opportunities for the Brown and Dark Brown Soil Zones of Saskatchewan

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Abstract

Producers, particularly in the Brown and drier parts of the Dark Brown soil zones, have begun to extend and diversify their crop rotations, becoming less reliant on summerfallow and monoculture cereal cropping. The areas planted to crops such as canola, mustard, flax, field pea, chickpea and lentil expanded dramatically in recent years, often into new or non-traditional production areas. These changes in land use practices are expected to continue, and perhaps grow in future years.

This study determines and compares the economic merits and relative riskiness (both production and market) of producing chickpea, field pea, lentil, mustard, canola, and flax with spring wheat, durum wheat or barley when grown on chemical fallow and zero-till stubble for various plausible product price scenarios. Field data collected at Swift Current, Scott and Congress were extended with use of a STELLA® model, to elucidate the short-term and the longer-term economic and environmental impacts of these newer cropping systems.

Our findings indicate that under current market conditions, risk averse producers in the Brown soil zone would typically choose either a 4-year Fallow-Chickpea-Wheat-Wheat rotation or a 5-year Durum-Chickpea-Mustard-Wheat-Lentil rotation. In the Dark Brown soil zone, risk averse producers would choose a 4-year Canola-Wheat-Lentil-Wheat rotation.

Introduction

Following above average rainfall years of the mid to late 90's, the semiarid prairie region of western Canada has seen precipitation levels subside, giving way to severe moisture deficits and wide spread drought conditions. These recent dry conditions have significantly reduced yields and potential farm revenues, leaving producers with the arduous task of managing their crops to make the best use of available moisture. Crop types and rotation selections are important management tools that allow producers to use available moisture more efficiently. This paper investigates the profitability of competing crop rotations in the Brown and Dark Brown soil zones of Saskatchewan.

Materials and Methods

Model Specification

The environmental sub-model was developed around a series of annual crop rotations for the Brown and Dark Brown soil zones. A "conventional" or traditional rotation was included in each soil zone. These rotations served as the benchmark management practices in the analysis and represent diversity level one. The alternative rotations were selected to be agronomically and technically suitable for the target regions and included pulse and oilseed crops in addition to the traditional cereal crops. Diversity level two rotations included either a pulse or an oilseed crop, and diversity level three contained at least one crop from each of the cereals, oilseeds and pulse categories. A complete list of the rotations simulated for the Brown soil zones are shown in Table 1 and for the Dark Brown soil zone in Table 2. The model simultaneously simulated all rotations in each soil zone to ensure that weather patterns were identical for all production systems. The simulation runs were replicated 100 times using randomized weather sequences (typical of each region) spanning a 60-year time horizon.

Environmental Model

Within the environmental sub-model, crop production potential is determined by soil quality, as represented by the ability of the soil to provide nutrients and water for crop growth. Soil quality is an endogenous variable that was determined by the study areas specific soil texture and climatic parameters as well as the cropping practices employed within the simulated rotations, including the influence of the crop varieties grown and method of tillage management used. To estimate crop yields the main function of the environmental model is to simulate the amount of nitrogen, phosphorus and water provided by the soil at each time step under each crop rotation.

Table 1. Crop rotations by diversity level for the Brown soil zone.

Diversity	Rotation	Abbreviation
Diversity level 1	Fallow-Wheat-Wheat	F-W-W
Diversity level 2	Fallow-Mustard-Wheat-Wheat	F-M-W-W
	Fallow-Wheat-Lentil-Wheat	F-W-L-W
	Fallow-Chickpea[a]-Wheat-Wheat	F-CP-W-W
	Fallow-Durum-Field Pea-Durum	F-D-FP-D
Diversity level 3	Fallow-Mustard-Wheat-Lentil-Wheat	F-M-W-L-W
	Fallow-Mustard-Wheat-Chickpea[a]-Wheat	F-M-W-CP-W
	Fallow-Chickpea[a]-Wheat-Mustard-Wheat	F-CP-W-M-W
	Durum-Chickpea[a]-Mustard-Wheat-Lentil	D-CP-M-W-L

[a]Chickpea type is Kabuli (large size).
[b]Mustard type is Brown.

Table 2. Crop rotations by diversity level for the Dark Brown soil zone.

Diversity	Rotation	Abbreviation
Diversity level 1	Fallow-Barley-Wheat	F-B-W
Diversity level 2	Canola[a]-Wheat-Field Pea	C-W-FP
	Field Pea-Wheat-Barley	FP-W-B
	Fallow-Canola[a]-Barley-Wheat	F-C-B-W
	Fallow-Wheat-Lentil-Wheat	F-W-L-W
Diversity level 3	Canola[a]-Wheat-Lentil-Wheat	C-W-L-W
	Canola[a]-Wheat-Barley-Field Pea	C-W-B-FP
	Canola[a]-Barley-Field Pea-Wheat	C-B-FP-W
	Flax-Barley-Lentil-Wheat	FX-B-L-W

[a]Canola type is Argentine type.

Economic Analyses

The economic performance of the nine crop rotations for the Brown and Dark Brown soil zones were analyzed on an annual basis. Each system was evaluated in regard to costs of production, net returns and riskiness. Net return was defined as gross income less total costs, including all cash costs (seed, fertilizer, pesticides, fuel, oil, repairs, crop insurance, property taxes, interest and miscellaneous items) and fixed costs (building and machinery investment and depreciation). Riskiness was assessed using stochastic dominance analysis (Goh et al. 1989) to compare the probability distributions of average annualized net incomes for groups of producers having low, medium and high risk aversion as defined by Zentner et al. (1992). The performance of each cropping system was also evaluated for a range of product prices (representing one standard deviation lower than the respective base price to one standard deviation higher than the respective base values) to test the sensitivity of the findings to changes in these price conditions.

Results and Discussion

Production Costs

Average costs of production for the nine crop rotations in each soil zone are shown in Table 3.

In the Brown soil zone, production costs increased as additional crops were added to the rotation. The lowest cost rotation was F-W-W ($181/ha) and the highest cost rotation was D-CP-M-W-L ($288/ha). In general, wheat, durum and mustard were the lowest cost crops to grow. Pulse crops had the highest costs, led by chickpea, lentil and field pea reflecting the high seeding rates and increased chemical use required for pulse production. On the other hand, N fertilizer costs were lowest for pulse crops, intermediate for mustard, and highest for the cereals. On a complete rotation basis, N fertilizer costs were highest for F-M-W-W ($24/ha) followed by F-W-W ($20/ha), with F-W-L-W, F-D-FP-D and F-CP-W-W having the lowest cost for N fertilizer at about $10/ha. The D-CP-M-W-L rotation had the highest pesticide cost ($70/ha), primarily due to the high use of fungicides with chickpea. The rotation with the lowest pesticide cost was F-W-W ($35/ha).

In the Dark Brown soil zone, production costs were lowest for F-B-W ($209/ha), F-C-W-B ($237/ha) and F-W-L-W ($242/ha). Each of the remaining six rotations had similar production costs ranging from $275/ha to $292/ha. Wheat had the lowest cost of production ($264/ha), followed by field pea, barley, flax and canola. The highest cost crop in the Dark Brown soil zone was lentil ($325/ha) due to higher seed and pesticide costs. Nitrogen fertilizer costs were highest for the oilseed crops, followed by the cereals and then pulses. The rotations with the highest average N fertilizer cost were F-C-B-W, C-B-FP-W and FX-B-L-W at $26/ha. The rotations with the highest pesticide cost included lentil, (i.e. C-W-L-W and FX-B-L-W) and ranged from 66$/ha to $70/ha. The rotation with the lowest pesticide cost was F-B-W ($44/ha).

Table 3. Average production costs for individual crops and complete rotations ($/ha).

	Phase -1	Phase-2	Phase-3	Phase-4	Phase-5	Rotation1
Brown						
F-W-W	77.00	236.65	229.41			181.03
F-M-W-W	77.00	260.20	231.46	226.34		198.74
F-W-L-W	77.00	235.66	306.60	225.75		211.25
F-CP-W-W	77.00	412.51	231.09	226.17		236.70
F-D-FP-D	77.00	231.46	307.22	221.43		209.27
F-M-W-L-W	77.00	260.57	229.06	299.36	227.60	218.71
F-M-W-CP-W	77.00	264.99	221.60	417.18	220.14	240.18
F-CP-W-M-W	77.00	419.50	221.28	247.57	220.26	237.12
D-CP-M-W-L	247.84	413.94	247.42	221.57	310.28	287.97
Dark Brown						
F-B-W	91.58	271.88	264.05			209.17
F-C-B-W	91.58	325.70	266.18	265.85		237.31
F-W-L-W	91.58	285.82	325.90	263.95		241.81
FP-W-B	291.70	272.18	263.53			275.81
C-W-FP	308.31	271.96	289.97			290.07
C-W-L-W	301.26	274.85	328.00	264.08		292.05
C-W-B-FP	298.72	274.90	264.69	285.08		280.85
C-B-FP-W	310.51	272.85	289.60	264.37		284.34
FX-B-L-W	283.62	274.01	322.51	255.08		283.82

<u>Net Returns</u>

Tables 4 and 5 show the mean, maximum, minimum and standard deviation for annual net returns for individual crops within each cropping system. In the Brown soil zone, chickpea grown after fallow in the F-CP-W-W rotation and in the F-CP-W-M-W rotation had the highest average annual net returns at $491/ha and $539/ha, respectively. The highest annual net return was earned with chickpea in the F-CP-W-M-W rotation at

$1219/ha, and the lowest was earned with wheat after lentil in the F-M-W-L-W rotation ($-146/ha).

In the Dark Brown soil zone, the highest average annual net return was earned with canola grown on fallow in the F-C-B-W rotation ($345/ha). The lowest average annual net return was earned with barley grown on wheat stubble at $-70/ha. The highest annual net return was obtained with wheat grown on field pea stubble in the C-W-FP-W rotation ($659/ha), and the lowest was obtained with barley grown on wheat stubble in this same rotation ($-265/ha).

On a complete rotation basis, net returns (over the 60-year simulation period) were highest for F-CP-W-M-W and D-CP-M-W-L in the Brown soil zone at $124/ha and $107/ha, respectively. F-W-W had the lowest average net return at $54/ha. In the Dark Brown soil zone, C-W-L-W had the highest average annual net return at $122/ha and F-B-W had the lowest ($34/ha).

A change in grain price will have its greatest impact on those cropping systems that devote a high proportion of the land area to that crop whose price has changed (Zentner et al. 2002). In the Brown soil zone, an increase in grain price of one standard deviation for all cereal crops (wheat and durum) above the base levels (prices for all other grains held constant) increased the mean net return of all rotations, but the relative improvement in profitability was greatest for the monoculture cereal rotation ($39/ha higher). Leaving the F-M-W-W rotation as the least profitable of all nine rotations. When cereal prices were decreased by one standard deviation, net returns decreased for all rotations. F-D-FP-D became the least profitable rotation. Increasing the price for mustard increased the net returns for all rotations that included mustard and improved the ranking of F-M-W-W (increased net returns 39%) ahead of the F-W-L-W rotation at base price levels. Increasing pulse prices (field pea, chickpea and lentil) favoured rotations that included lentil due to lentil having the highest standard deviation among the pulses. In general, increasing the pulse price by one standard deviation increases net returns by 23-37% for rotations including at least one pulse crop.

In the Dark Brown soil zone, increasing the price of cereals (wheat and barley) increased the mean net return of all rotations and improved the ranking of F-W-L-W to number two from number three. Decreasing cereal prices resulted in negative returns for the F-B-W rotation but did not change the ranking of the rotations. Increasing oilseed prices (canola and flax) by one standard deviation increased the mean net return of rotations with at least one oilseed from 24 to 45%, also increasing the ranking of the C-W-FP rotation from six to two. Decreasing pulse price (field pea and lentil) did not change the ranking of the rotations. C-W-L-W ranked highest across all price scenarios.

Financial Risk

In the case of agricultural production, risk is defined as the difference between what an individual producer perceives to be the consequence or outcome associated with a particular action and what actually occurs (Boehlje and Eidman, 1983). The effects of exogenous factors such as weather, disease, and insects combined with unknown input and output prices, makes farm management decisions inherently risky. As a result, output variables, such as crop yields, net incomes, and equity positions cannot be determined with certainty. These imperfect conditions present producers with the problem of having to make production decisions based on a number of competing alternatives, without prior knowledge of the final outcome of their selection. Therefore, the success of the farming enterprise is dependent on the ability of the farm manager to select strategies that provide the greatest probability of maximizing the goals of the farm.

When producers choose among cropping systems they must consider the trade-off between increased annual net returns and increased income variability or financial risk. Risk averse producers tend to choose cropping systems that display lower income variability. Therefore their final choice or selection of a cropping system depends on the risk attitudes of the individual, their expectations of product prices and input costs, and the nature of distributions of probable net returns that can be earned with each cropping system. The results of the stochastic dominance analysis the Brown and Dark Brown soil zones are shown in Tables 6 and 7, respectively.

At the base price levels, producers in the Brown soil zone (regardless of the level of risk aversion would prefer the F-CP-W-M-W rotation (Table 6). In the Dark Brown soil zone producers with low or high risk aversion would choose the C-W-L-W rotation (Table 7).

In general, producers in the Brown soil zone with a medium to high aversion to risk would prefer rotations that include at least one pulse crop and one cereal crop. Mustard would be included in the rotation of a medium to high-risk averse producer only when cereal prices are low or oilseed prices are high. Three of the nine rotations would never be chosen regardless of risk preference: F-W-W, F-M-W-W and F-M-W-CP-W.

Table 4. Net returns for crop rotations under various price scenarios in the Brown soil zone

			Brown Soil Zone		
Rotation	Base Prices	High prices for all crops	High prices for cereal crops	High prices for Oilseed Crops	High price for Pulse crops
F-W-W	54	95	95	54	54
F-M-W-W	65	130	91	105	65
F-W-L-W	82	131	112	82	101
F-CP-W-W	119	164	144	119	139
F-D-FP-D	60	126	112	60	74
F-M-W-L-W	80	144	100	109	95
F-M-W-CP-W	81	143	101	112	93
F-CP-W-M-W	124	182	143	146	141
D-CP-M-W-L	107	205	153	129	157
Rotation	Base Prices	Low prices for all crops	Low prices for cereal crops	Low prices for Oilseed Crops	Low price for Pulse crops
F-W-W	54	13	13	54	54
F-M-W-W	65	0	40	23	65
F-W-L-W	82	33	53	82	63
F-CP-W-W	119	74	94	119	99
F-D-FP-D	60	-7	7	60	60
F-M-W-L-W	80	15	60	49	64
F-M-W-CP-W	81	20	62	49	70
F-CP-W-M-W	124	65	105	101	106
D-CP-M-W-L	107	49	81	85	97

Table 5. Net returns for price scenarios in the Dark Brown soil zone

	Dark Brown Soil Zone				
Rotation	Base Prices	High prices for all crops	High prices for cereal crops	High prices for Oilseed Crops	High price for Pulse crops
F-B-W	34	90	90	34	34
C-W-FP	67	136	87	94	89
F-C-B-W	58	124	91	92	58
F-W-L-W	91	146	125	91	112
FP-W-B	57	122	100	57	80
C-W-L-W	122	200	151	151	143
C-W-B-FP	55	125	91	74	70
C-B-FP-W	60	136	95	87	60
FX-B-L-W	105	184	138	129	125
Rotation	Base Prices	Low prices for all crops	Low prices for cereal crops	Low prices for Oilseed Crops	Low price for Pulse crops
F-B-W	34	-22	-22	34	34
C-W-FP	67	-1	47	40	46
F-C-B-W	58	-8	26	25	58
F-W-L-W	91	35	56	91	70
FP-W-B	57	-7	15	57	35
C-W-L-W	122	44	93	93	101
C-W-B-FP	55	-15	19	36	40
C-B-FP-W	60	-15	26	33	46
FX-B-L-W	105	25	71	80	84

Table 6. Risk efficient rotations at various grain prices for the Brown soil zone

	Level of risk aversion[a]		
Grain price scenarios	Low	Medium	High
Base prices	F-CP-W-M-W	F-CP-W-M-W	F-CP-W-M-W
High prices for all crops	F-W-L-W F-M-W-L-W D-CP-M-W-L	F-W-L-W	F-W-L-W
Low prices for all crops	F-CP-W-W	F-CP-W-W	F-CP-W-W
High cereal prices	F-D-FP-D D-CP-M-W-L	F-D-FP-D	F-D-FP-D
Low cereal prices	F-CP-W-M-W	F-CP-W-M-W	F-CP-W-M-W
High oilseed prices	D-CP-M-W-L	D-CP-M-W-L	D-CP-M-W-L
Low oilseed prices	F-CP-W-W F-D-FP-D D-CP-M-W-L	F-D-FP-D	F-D-FP-D
High pulse prices	F-CP-W-W	F-CP-W-W	F-CP-W-W
Low pulse prices	F-CP-W-W F-D-FP-D F-CP-W-M-W D-CP-M-W-L	F-CP-W-M-W	F-CP-W-M-W

[a]The Pratt-Arrow coefficients of absolute risk aversion were defined as low = 0 - .0075, medium = .0075 - .0225, and high = .0225 - .05. The low, medium and high designations are becoming less willing to gamble or accept risk.

In the Dark Brown soil zone, the C-W-L-W rotation would be preferred by medium to high risk averse producers for all price scenarios except when oilseed or all crop prices are low, or when cereal prices are high. Under low cereal prices, risk averse producers would prefer the C-W-FP rotation. When all crop prices or cereal prices are high, or when oilseed prices are low, producers with low risk aversion would prefer the FP-W-B rotation.

Table 7. Risk efficient rotations at various grain prices for the Dark Brown soil zone

	Level of risk aversion[a]		
Grain price scenarios	Low	Medium	High
Base prices	C-W-L-W	C-W-L-W	C-W-L-W
High prices for all crops	C-W-L-W	C-W-L-W	C-W-L-W
Low prices for all crops	FP-W-B C-W-L-W	FP-W-B	FP-W-B
High cereal prices	FP-W-B C-W-L-W	FP-W-B	FP-W-B
Low cereal prices	C-W-L-W	C-W-FP C-W-L-W	C-W-FP
High oilseed prices	C-W-L-W	C-W-L-W	C-W-L-W
Low oilseed prices	FP-W-B C-W-L-W	FP-W-B	FP-W-B
High pulse prices	C-W-L-W	C-W-L-W	C-W-L-W
Low pulse prices	C-W-L-W	C-W-L-W	C-W-L-W

[a]The Pratt-Arrow coefficients of absolute risk aversion were defined as low = 0 - .0075, medium = .0075 - .0225, and high = .0225 - .05. The low, medium and high designations are becoming less willing to gamble or accept risk.

Conclusions

The objective of this study was to investigate the agronomic and economic merits of mixed cropping alternatives (pulses and oilseeds) to monoculture cereal systems, for the Brown and Dark Brown soil zones, and to determine if these diversified cropping systems enhance the overall economic and environmental sustainability of annual cropping systems in these regions. Under current market conditions, risk averse producers in the Brown soil zone would generally choose the F-CP-W-M-W rotation, which includes 20% summerfallow. In the Dark Brown soil zone risk averse producers would choose the continuous cropping C-W-L-W rotation.

In this investigation, the addition of pulse and oilseed crops to cereal-based rotations contributed positively to the profitability of farm enterprises in both soil zones. By extending crop rotations, producers are able to diversify their income source, create new marketing opportunities, capture rotational benefits, raise productivity, and spread out the workload in peak periods. Extended rotations also enhance cash flow as a result of being able to vary harvest dates, avoid restrictive quotas, and enter into planned delivery contracts throughout the year. Rotational benefits provide additional income enhancement opportunities through managing protein levels, reducing nitrogen requirements for crops following pulses, using the limited water more efficiently and benefiting from the micro-environment effects created by the various crop stubble types.

The negative implications of increasing cropping diversity are increased reliance on herbicides and pesticides, greater demand on management skills, and higher production risk. The increase in springtime cash outlay can be minimized with production contracts. However, this method of marketing tends to be restrictive and inflexible when commodity prices take favourable upward swings. Another pitfall to consider, with non-cereal crops is the lack of efficient secondary markets for downgraded commodities. This may make the liquidation of lower quality grain samples difficult.

Extending cereal-fallow based rotations with oilseed and pulse crops and reducing fallow frequency, contributes to higher net farm incomes, in both the Brown and Dark Brown soil zones, despite higher production costs. In this investigation the superior economic performance of the extended rotations can be attributed to the production of higher-valued crops and the accompanying rotational benefits, such as greater residual soil nutrients and moisture reserves and reduced soil losses. Although grain quality issues were not addressed specifically in this study, (Miller et al. 1997) other studies suggest that these rotational benefits enhance grain quality of subsequent cereal crops, and lower their unit costs of production.

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