Building Successful Cropping Systems

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INTRODUCTION

Low prices for cereal grains and declining costs for some inputs (e.g., glyphosate), coupled with changes in government policies and programs (e.g., grain transportation, farm safety net programs), development of value-added opportunities, improvements in machine design and soil management practices, and growing concerns about soil and environmental degradation are stimulating significant change in land use practices throughout western Canada (Campbell et al. 2002). Consequently, producers are becoming less reliant on summerfallow and monoculture cereal cropping. The areas planted to oilseed and pulse crops such as canola, mustard, field pea, lentil, and chickpea are expanding dramatically in recent years, often into new or non-traditional production regions. Further, the use of minimum-tillage and zero-tillage practices are becoming integral management strategies for these newer cropping alternatives.

For these newer cropping systems to be sustainable in the long-term, however, they must: (i) be technically or agronomically feasible (i.e., suited to the soil and climatic conditions of the area, practical to implement, and capable of producing acceptable grain yields and quality); (ii) ensure that the quality of the soil, water, and air resources are maintained or enhanced; and (iii) be economically viable (Campbell et al. 1995). This paper focuses primarily on the latter aspect. We examine some of the main economic factors influencing producers' choices of these newer cropping systems for the semiarid Brown and Dark Brown soil zones.

MATERIALS AND METHODS

The study determines and compares the economic merits and relative riskiness (both production and market) of producing chickpea, field pea, lentil, mustard, canola, and flax when grown in combination with spring wheat, durum, and barley for various plausible product price scenarios. The study draws on data from three completed field experiments, one conducted at the Semiarid Prairie Agricultural Research Centre at Swift Current (1992 to 1996), a second on a producer's field at Congress (1994 to 1996), and a third conducted at the Scott Experimental Farm also during the 1990s. These data were extrapolated to the farm-level and extended with the use of a computer simulation model (Wall et al. 2002) to represent nine cropping systems in each soil zone (Table 1). (A detailed description of the computer model can be found in Wall et al. 2002).

All cropping systems were assumed to be managed using zero-tillage methods. The economic analyses used 2002 output price estimates (Table 2) and cost of production data for each crop and soil zone (Table 3) as provided by Saskatchewan Agriculture and Food (2002a,b,c). Total production costs include seed, pesticides, fertilizers, fuel and oil, machine repair, custom work, hired labor, crop insurance, property taxes, interest, plus depreciation and investment for machines and buildings. The costs do not include allowances for operator labor or land equity.

Nitrogen and phosphorus fertilizer rates were estimated by the computer model based on soil nutrient reserves and mineralization rates, which were a function of soil organic matter levels, crop residue type and quantity returned to the soil, soil moisture conditions, and solar energy input. The unit costs for N and P_2O_5 fertilizers were set at \$0.26/lb and \$0.30/lb, respectively. Soil texture was assumed to be loam to clay-loam. Each cropping system was evaluated for 100 replications of 60-year randomized weather sequences typical of each region, so as to permit the long-term consequences of each cropping system on soil quality to become expressed in crop yields and inorganic fertilizer requirements. Annual crop yields were estimated by the computer model based on the amounts of total N and P (soil plus fertilizer) and available water (soil plus growing season rainfall). The model does not capture the effects of diseases or weeds, nor the effects of crop rotations on grain protein concentrations.

Table 1. Summary of crop rotations by soil zone.

Soil Zone	Crop Rotation	Abbreviation
Brown	Fallow-Wheat-Wheat[1]	F-W-W
	Fallow-Mustard[2]-Wheat-Wheat	F-M-W-W
	Fallow-Wheat-Lentil-Wheat	F-W-L-W
	Fallow-Chickpea[3]-Wheat-Wheat	F-CP-W-W
	Fallow-Durum-Field Pea-Durum	F-D-FP-D
	Fallow-Mustard[2]-Wheat-Lentil-Wheat	F-M-W-L-W
	Fallow-Mustard[2]-Wheat-Chickpea[3]-Wheat	F-M-W-CP-W
	Fallow-Chickpea[3]-Wheat-Mustard[2]-Wheat	F-CP-W-M-W
	Durum-Chickpea[3]-Mustard[2]-Wheat-Lentil	D-CP-M-W-L
Dark Brown	Fallow-Barley-Wheat[1]	F-B-W
	Fallow-Canola[4]-Barley-Wheat	F-C-B-W
	Fallow-Wheat-Lentil-Wheat	F-W-L-W
	Field Pea-Wheat-Barley	FP-W-B
	Canola[4]-Wheat-Field Pea	C-W-FP
	Canola[4]-Wheat-Lentil-Wheat	C-W-L-W
	Canola[4]-Wheat-Barley-Field Pea	C-W-B-FP
	Canola[4]-Barley-Field Pea-Wheat	C-B-FP-W
	Flax-Barley-Lentil-Wheat	FX-B-L-W

[1] Benchmark rotation.
[2] Brown mustard.
[3] Kabuli chickpea.
[4] Argentine canola.

The economic performance of each cropping system was evaluated in regard to costs of production, net returns, and riskiness. Net return was defined as gross income from grain sales less total production costs. Riskiness was assessed using stochastic dominance analysis (Goh et al. 1989) to compare the probability distributions of average annualized net return 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 (Table 2) to test the sensitivity of the findings to changes in these price conditions. The economic results were expressed on a per acre basis for individual crops within each rotation, and for the complete rotation systems.

Table 2. Net farm-gate prices for grains ($/bu).

Crop	Average Price	Low Price	High Price
Wheat	4.68	3.87	5.50
Durum	4.79	3.40	6.18
Barley	2.31	1.63	3.73
Field Pea	4.60	3.87	5.34
Kabuli Chickpea	14.97	13.56	16.39
Lentil	10.18	8.60	11.76
Brown Mustard	7.06	4.67	9.44
Canola	6.07	4.56	7.60
Flax	6.99	5.41	8.56

From a producer's perspective, there is an economic incentive to employ that cropping system that provides the greatest (net) return to management and risk taking in the short-term, and to land equity and other fixed assets of production in the long-term. Consequently, profit-motivated producers will seek to adopt a new cropping system only if it is perceived to provide a net economic benefit relative to a currently used system, in terms of lower production costs, higher net returns, lower business risk, or some combination of these. Producers seeking to adopt these newer farming systems also need to balance net returns earned in the short-term against the possibility of higher costs and lower returns in the longer-term from choosing crop rotations and/or management practices that do not adequately conserve the quality of the soil, water and air resources.

<u>Impact on Production Costs</u>

Production costs increased as the rotations were extended (i.e., less summerfallow) and diversified (Table 3). The lowest cost rotations in both soil zones were the fallow-monoculture cereal systems, or benchmark rotations ($73/ac for F-W-W in the Brown and $85/ac for F-B-W in the Dark Brown soil zone). Pulse crops had the highest production costs per unit of land area, led by chickpea ($170/ac), and then lentil ($125 to 135/ac), field pea ($115 to 125/ac), the oilseeds ($100 to $125/ac), and finally the cereals ($90 to $110/ac). While the pulse crops required lower expenditures for N fertilizer than for cereals or oilseeds, these savings were more than offset by higher expenditures for seed, inoculant, pesticides, and machine operation and overhead.

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

	Phase -1	Phase-2	Phase-3	Phase-4	Phase-5	Rotation[1]
Brown						
F-W-W	31.16	95.77	92.84			73.26
F-M-W-W	31.16	105.30	93.67	91.60		80.43
F-W-L-W	31.16	95.37	124.08	91.36		85.49
F-CP-W-W	31.16	166.94	93.52	91.53		95.79
F-D-FP-D	31.16	93.67	124.33	89.61		84.69
F-M-W-L-W	31.16	105.45	92.70	121.15	92.11	88.51
F-M-W-CP-W	31.16	107.24	89.68	168.83	89.09	97.20
F-CP-W-M-W	31.16	169.77	89.55	100.19	89.14	95.96
D-CP-M-W-L	100.30	167.52	100.13	89.67	125.57	116.54
Dark Brown						
F-B-W	37.06	110.03	106.86			84.65
F-C-B-W	37.06	131.81	107.72	107.59		96.04
F-W-L-W	37.06	115.67	131.89	106.82		97.86
FP-W-B	118.05	110.15	106.65			111.62
C-W-FP	124.77	110.06	117.35			117.39
C-W-L-W	121.92	111.23	132.74	106.87		118.19
C-W-B-FP	120.89	111.25	107.12	115.37		113.66
C-B-FP-W	125.66	110.42	117.20	106.99		115.07
FX-B-L-W	114.78	110.89	130.52	103.23		114.86

[1] Represents the average cost meaned across all phases of the rotation. For example, a 2000 acre farm employing a F-W-W rotation could expect to spend (2000 x 73.26) $146,520 to cover the costs of all purchased inputs plus machine and building overhead associated with using this cropping system.

The costs per unit of grain produced are shown in Table 4 and Table 5 for the Brown and Dark Brown soil zones, respectively. These values represent the minimum grain price that is required to recover all production costs, and as such they represent 'breakeven points' (between making a profit and incurring a loss) for producing that crop type. The average unit cost of producing wheat or durum ranged from $3.45 to $4.19/bu depending upon rotation, previous crop type, and soil zone. Similarly, the unit cost of producing barley ranged from $2.20 to $2.60/bu, mustard from $5.27 to $5.45/bu, canola from $4.07 to $5.86/bu, lentil from $5.95 to $6.14/bu, chickpea $8.33 to $10.42/bu, and field pea from $3.30 to $4.00/bu. Overall, the differences in unit cost of producing the various crops due to rotation choice were not large, nor were they always consistent. These results reflect, in part, the tradeoffs that are occurring, for example between some N fertilizer savings for crops grown after a pulse (compared to after a cereal or oilseed) versus somewhat lower spring soil water reserves after a pulse (in some years) due to its lesser ability to trap snow. In addition, some rotations produce improvements in soil organic matter which influences soil nutrient availability and water holding capacity, and this in turn, influences fertilizer requirements and crop yields.

Table 4. Average cost of producing grain in the Brown soil zone ($/bu).

Crop	Cost per unit of grain produced[1]
Wheat on fallow	3.76
Wheat on wheat stubble	3.56
Wheat on mustard stubble	3.98
Wheat on lentil stubble	3.51
Wheat on chickpea stubble	3.84
Durum on fallow	3.57
Durum on lentil stubble	3.88
Durum on field pea stubble	3.43
Mustard on fallow	5.27
Mustard on wheat stubble	5.40
Mustard on chickpea stubble	5.45
Lentil on wheat stubble	5.95
Chickpea on fallow	8.33
Chickpea on wheat stubble	10.42
Chickpea on durum stubble	10.06
Field pea on durum stubble	4.00

[1] Crops grown on fallow include the costs of summerfallowing

Impact on Net Returns

Table 6 and Table 7 show the mean, maximum, and minimum annual net returns (based on the 100 sets of 60-year weather sequences) for individual crops within each cropping system. In the Brown soil zone (Table 6), chickpea grown on fallow in the F-CP-W-W and F-CP-W-M-W rotations provided the highest average annual net returns at $160/ac (after deducting the cost of summerfallow). The second most profitable cropping components, with about one-half the level of net earnings, included lentil grown on wheat stubble and chickpea grown on durum stubble. The net returns from producing wheat, durum, and mustard (after accounting for costs of summerfallow where appropriate) were among the lowest, ranging from about $20 to $40/ac. Only one rotation included field pea production, and its average net earning were also quite low at about $20/ac. In contrast to the mean net returns, the annual variability in net returns (as measured by the range or difference between the maximum and minimum values) was generally highest for chickpea and mustard production, intermediate for lentil and field pea, and lowest for wheat and durum. These latter results suggest that the earnings from these new or alternative crops types may be more sensitive to weather, so in years of favorable growing conditions they earn very high profits, but in years of poor growing conditions, they also have the potential for significant economic losses.

Table 5. Average cost of producing grain in the Dark Brown soil zone ($/bu).

Crop	Cost per unit of grain produced[1]
Wheat on fallow	3.57
Wheat on barley stubble	3.71
Wheat on canola stubble	3.45
Wheat on lentil stubble	4.19
Wheat on field pea stubble	3.91
Barley on fallow	2.41
Barley on wheat stubble	2.60
Barley on canola stubble	2.24
Barley on flax stubble	2.20
Canola on fallow	4.71
Canola on wheat stubble	4.07
Canola on field pea stubble	5.86
Flax on wheat stubble	4.59
Lentil on wheat stubble	6.14
Lentil on barley stubble	6.06
Field pea on wheat stubble	3.30
Field pea on barley stubble	3.45

[1] Crops grown on fallow include the cost of summerfallowing.

In the Dark Brown soil zone (Table 7), the highest average annual net returns were earned with lentil grown on wheat or barley stubble ($87/ac). This was followed by canola grown on fallow or wheat stubble and by flax grown on wheat stubble (about $60/ac). The lowest net returns were earned with barley grown on wheat stubble in the FP-W-B rotation and by wheat grown on canola stubble in the C-W-B-FP rotation. Annual variability in net returns also tended to be highest for the oilseeds and pulses and lowest for the cereal crops.

On a complete rotation basis, net returns in the Brown soil zone (Table 8) were highest for F-CP-W-W, F-CP-W-M-W, and D-CP-M-W-L at $43 to $50/ac. The F-W-L-W, F-M-W-L-W, and F-M-W-CP-W rotations ranked intermediate generating an average annual net return of $32/ac, while the benchmark rotation (F-W-W) together with F-M-W-W and F-D-FP-D provided the lowest net return. In the Dark Brown soil zone, F-W-L-W, C-W-L-W, and FX-B-L-W earned the highest average annual net returns at $37 to $49/ac. The least profitable rotation was F-B-W at $14/ac.

Table 6. Average annual net return by crop type for the Brown soil zone ($/ac).

		Gross Returns	Net Returns		
Rotation	**Crop**	**Mean**	**Mean**	**Maximum**	**Minimum**
F-W-W	Fallow	0.00	-31.16	-31.16	-31.16
	Wheat on fallow	155.64	59.87	140.81	-26.66
	Wheat on wheat	129.33	36.49	122.47	-46.26
F-M-W-W	Fallow	0.00	-31.16	-31.16	-31.16
	Mustard on fallow	191.22	85.92	180.30	-57.57
	Wheat on mustard	118.89	25.22	120.17	-40.56
	Wheat on wheat	117.08	25.48	82.07	-48.70
F-W-L-W	Fallow	0.00	-31.16	-31.16	-31.16
	Wheat on fallow	159.87	64.49	105.02	-26.24
	Lentil on wheat	200.60	76.51	221.23	-28.15
	Wheat on lentil	114.62	23.26	77.65	-49.32
F-CP-W-W	Fallow	0.00	-31.16	-31.16	-31.16
	Chickpea on fallow	342.33	175.39	444.24	-14.25
	Wheat on chickpea	115.50	21.99	125.61	-46.48
	Wheat on wheat	117.68	26.15	102.28	-20.88
F-D-FP-D	Fallow	0.00	-31.16	-31.16	-31.16
	Durum on fallow	167.10	73.43	117.41	-15.48
	Field Pea on durum	143.03	18.70	177.61	-56.24
	Durum on field pea	125.03	35.41	89.24	-47.17
F-M-W-L-W	Fallow	0.00	-31.16	-31.16	-31.16
	Mustard on fallow	175.16	69.71	250.36	-60.41
	Wheat on mustard	100.52	7.83	73.16	-42.57
	Lentil on wheat	197.01	75.87	161.59	-28.37
	Wheat on lentil	130.86	38.75	69.11	-65.66
F-M-W-CP-W	Fallow	0.00	-31.16	-31.16	-31.16
	Mustard on fallow	184.91	77.67	243.29	-62.70
	Wheat on mustard	96.41	6.73	74.68	-40.79
	Chickpea on wheat	243.17	74.35	223.90	-47.93
	Wheat on chickpea	126.28	37.19	71.36	-62.91
F-CP-W-M-W	Fallow	0.00	-31.16	-31.16	-31.16
	Chickpea on fallow	376.91	207.14	459.35	-108.00
	Wheat on chickpea	94.55	5.00	88.88	-69.47
	Mustard on wheat	131.31	31.12	241.72	-49.98
	Wheat on mustard	127.21	38.07	73.00	-44.42
D-CP-M-W-L	Durum on lentil	124.23	23.93	95.69	-46.85
	Chickpea on durum	248.74	81.22	310.40	-1.71
	Mustard on chickpea	129.32	29.19	197.62	-69.67
	Wheat on mustard	97.86	8.18	112.17	-52.09

Lentil on wheat	199.80	74.23	182.34	-26.25

Table 7. Average annual net return by crop type for the Dark Brown soil zone ($/ac).

		Gross Returns	Net Returns		
Rotation	**Crop**	**Mean**	**Mean**	**Maximum**	**Minimum**
F-B-W	Fallow	0.00	-37.13	-37.13	-37.13
	Barley on fallow	140.88	30.85	138.35	-43.54
	Wheat on barley	154.46	47.60	121.45	-62.31
F-C-B-W	Fallow	0.00	-37.13	-37.13	-37.13
	Canola on fallow	218.00	93.42	185.97	-8.17
	Barley on canola	107.87	12.51	98.62	-67.39
	Wheat on barley	120.33	25.46	114.46	-65.82
F-W-L-W	Fallow	0.00	-37.13	-37.13	-37.13
	Wheat on fallow	200.47	84.80	154.40	27.02
	Lentil on wheat	220.47	88.59	207.15	-15.34
	Wheat on lentil	117.22	10.40	105.49	-67.14
FP-W-B	Field Pea on barley	171.94	53.89	210.92	-33.25
	Wheat on field pea	141.30	31.15	128.60	-37.07
	Barley on wheat	91.35	-15.30	58.08	-87.35
C-W-FP	Canola on field pea	131.02	6.25	146.38	-84.64
	Wheat on canola	139.25	29.19	128.00	-40.45
	Field Pea on wheat	163.56	46.21	150.07	-63.32
C-W-L-W	Canola on wheat	186.19	64.27	161.16	-32.98
	Wheat on canola	148.54	37.31	126.82	-26.31
	Lentil on wheat	217.25	84.51	204.79	-22.25
	Wheat on lentil	118.38	11.51	107.52	-65.80
C-W-B-FP	Canola on field pea	123.74	25.24	192.12	-74.39
	Wheat on canola	166.59	-19.08	49.59	-82.28
	Barley on wheat	98.52	35.31	206.30	-91.21
	Field Pea on barley	155.02	46.14	156.12	-63.84
C-B-FP-W	Canola on wheat	176.06	55.17	150.25	-43.89
	Barley on canola	118.03	2.97	108.39	-64.49
	Field Pea on barley	143.17	36.05	167.82	-38.05
	Wheat on field pea	120.61	5.00	102.50	-73.61
FX-B-L-W	Flax on wheat	175.17	60.39	147.86	-21.30
	Barley on flax	116.08	5.19	105.75	-64.13
	Lentil on barley	218.96	88.44	208.51	-12.46
	Wheat on lentil	118.38	15.15	111.17	-62.16

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 type whose price has changed, and/or to those cropping systems that foster a yield advantage for that crop type (Zentner et al. 2002). In the Brown and Dark Brown soil zones, increases or decreases in price for the various crop types (prices for other grains held constant), although impacting the level of net returns earned, had relatively little effect on the overall rankings of the group of best rotations (Table 8). Had this study included 2-year rotations such as F-W or F-C, or continuous-monoculture rotations such as continuous wheat, the effect of changes in grain price would have been much larger (Zentner et al. 2002).

Impact of Riskiness

Income variability or business risk arises from yield risk, market risk, or both. Yield risk, in turn, arises from variations in the amount and distribution of weather events, frequency and severity of crop pests, and effects of management practices on soil moisture conservation, nutrient dynamics, and other factors influencing plant growth and development. Market risk originates from unexpected changes in inputs costs and product prices as a result of market adjustments, capital purchases, changes in government policy and programs, and international events and agreements.

Decision-making in risky situations often entails making a trade-off between the potential to earn higher net returns on one hand, and having to accept a higher level of income variability on the other hand. The amount of income variability (or risk) that producers are willing to accept depends on their personal preferences, attitudes towards risk, and financial or wealth position. Producers who are less willing to gamble (i.e., more risk averse) will often forgo production opportunities that offer significant increases in net return but have higher income variability, for those production systems that offer lower net returns but also lower risk.

The results of the stochastic dominance analysis, which compared the probability distributions of net returns for each cropping system, are shown for the Brown soil zone in Table 9 and for the Dark Brown soil zone in Table 10. At the base or average grain price levels, producers in the Brown soil zone would prefer (or choose) the F-CP-W-M-W rotation, while producers in the Dark Drown soil zone would choose C-W-L-W, regardless of their level of risk aversion. This reflects that these cropping systems provide the highest and most stable distribution of net returns at the average grain price levels. However, at other grain price combinations, producers, particularly in the Brown soil zone, would also consider other cropping systems. For example, if all grains were valued at their highest price levels, producers with low risk aversion (i.e., those most willing to gamble) would prefer either F-W-L-W, F-M-W-L-W or D-CP-M-W-L; note, the first two rotations are not among the top three most profitable rotations when considering only the ‘average’ annual net returns (Table 8). In general, producers in the Brown soil zone with 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 medium to high-risk averse producers only when cereal prices are low or oilseed prices are high. Three of the nine rotations would never be chosen regardless of risk preference or grain price, namely F-W-W, F-M-W-W, and F-M-W-CP-W.

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 these latter price scenarios conditions, these producers would prefer the FP-W-B rotation. Producers with low risk aversion would consider either the FP-W-B or C-W-L-W rotations when all crop prices are low, cereal prices are high, or when oilseed prices are low.

Table 8. Annual net returns for complete rotations in the Brown and Dark Brown soil zones ($/ac).

Brown Soil Zone

Rotation	Base prices	High price for all crops	High price for cereal crops	High price for oilseed crops	High price for pulse crops
F-W-W	22	38	38	22	22
F-M-W-W	26	53	37	43	26
F-W-L-W	33	53	45	33	41
F-CP-W-W	48	66	58	48	56
F-D-FP-D	24	51	45	24	30
F-M-W-L-W	32	58	40	44	38
F-M-W-CP-W	33	58	41	45	38
F-CP-W-M-W	50	74	58	59	57
D-CP-M-W-L	43	83	62	52	64
Rotation	Base prices	Low price for all crops	Low price for cereal crops	Low price for oilseed crops	Low price for pulse crops
F-W-W	22	5	5	22	22
F-M-W-W	26	0	16	9	26
F-W-L-W	33	14	21	33	25
F-CP-W-W	48	30	38	48	40
F-D-FP-D	24	-3	3	24	18
F-M-W-L-W	32	6	24	20	26
F-M-W-CP-W	33	8	25	20	28
F-CP-W-M-W	50	26	42	41	43
D-CP-M-W-L	43	20	33	34	39

Dark Brown Soil Zone

Rotation	Base prices	High price for all crops	High price for cereal crops	High price for oilseed crops	High price for pulse crops
F-B-W	14	37	37	14	14
F-C-B-W	24	50	37	37	24
F-W-L-W	37	59	51	37	45
FP-W-B	23	50	40	23	32
C-W-FP	27	55	35	38	36
C-W-L-W	49	81	61	61	58
C-W-B-FP	22	51	37	30	29
C-B-FP-W	24	55	38	35	24
FX-B-L-W	42	74	56	52	51
Rotation	Base Prices	Low price for all crops	Low price for cereal crops	Low price for oilseed crops	Low price for pulse crops
F-B-W	14	-9	-9	14	14
F-C-B-W	24	-3	10	10	24
F-W-L-W	37	14	23	37	28
FP-W-B	23	-3	6	23	14
C-W-FP	27	-1	19	16	19
C-W-L-W	49	18	38	38	41
C-W-B-FP	22	-6	8	15	16
C-B-FP-W	24	-6	11	13	19
FX-B-L-W	42	10	29	32	34

Table 9. Risk efficient rotations at various grain prices for the Brown soil zone.

	Level of risk aversion[a]		
Grain price scenario	**Low**	**Medium**	**High**
Base prices	F-CP-W-M-W	F-CP-W-M-W	F-CP-W-M-W
High price 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 price for all crops	F-CP-W-W	F-CP-W-W	F-CP-W-W
High price for cereals	F-D-FP-D D-CP-M-W-L	F-D-FP-D	F-D-FP-D
Low price for cereals	F-CP-W-M-W	F-CP-W-M-W	F-CP-W-M-W
High price for oilseeds	D-CP-M-W-L	D-CP-M-W-L	D-CP-M-W-L
Low price for oilseeds	F-CP-W-W F-D-FP-D D-CP-M-W-L	F-D-FP-D	F-D-FP-D
High price for pulses	F-CP-W-W	F-CP-W-W	F-CP-W-W
Low price for pulses	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.

CONCLUSIONS

This study examined the economic merits of extending and diversifying crop rotations in the Brown and Dark Brown soil zones to determine if these newer cropping systems would enhance the overall economic and environmental sustainability of annual cropping in these regions. Under the 2002 market conditions, risk averse producers in the Brown soil zone would find the F-W-L-W, F-CP-W-W, F-D-FP-D, F-M-W-L-W, F-CP-W-M-W, and D-CP-M-W-L rotations (depending upon grain prices and risk preferences) all to be more profitable and risk efficient than a traditional F-W-W rotation, despite higher expenditures for production inputs. Similarly, producers in the Dark Brown soil zone would choose a C-W-L-W or FB-W-B rotation. By extending and diversifying their 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 also 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.

Table 10. Risk efficient rotations at various grain prices for the Dark Brown soil zone.

Grain price scenario	Level of risk aversion[a] Low	Medium	High
Base prices	C-W-L-W	C-W-L-W	C-W-L-W
High price for all crops	C-W-L-W	C-W-L-W	C-W-L-W
Low price for all crops	FP-W-B C-W-L-W	FP-W-B	FP-W-B
High price for cereals	FP-W-B C-W-L-W	FP-W-B	FP-W-B
Low price for cereals	C-W-L-W	C-W-FP C-W-L-W	C-W-FP
High price for oilseeds	C-W-L-W	C-W-L-W	C-W-L-W
Low price for oilseeds	FP-W-B C-W-L-W	FP-W-B	FP-W-B
High price for pulses	C-W-L-W	C-W-L-W	C-W-L-W
Low price for pulses	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.

The negative implications of increasing cropping diversity are the increased reliance on herbicides and pesticides, greater demand on management time to monitor developing pest problems (disease, weeds, insects) and devising control strategies, and higher production risk due to some crop types being more sensitive to drought and high temperature stress. The increase production risk can be partly offset through crop insurance, while the high spring-time cash outlay can be minimized with production contracts. However, this method of marketing tends to be restrictive and inflexible when commodity prices take favorable upward swings. Another factor to consider with non-cereal crops is the lack of efficient secondary markets for downgraded commodities. This may make the liquidation of lower quality grains more difficult, as is being widely experienced by producers in the current crop-year.

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