An Economic Analysis Of Crop Selection Under Risk in the Brown and Dark-Brown Soils of Saskatchewan

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by

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Introduction

Each year Saskatchewan farmers must evaluate whether to crop or fallow, and if to crop, what crop to grow. These fundamental farm decisions are complicated by uncertain prices and uncertain weather patterns and therefore, uncertain yields. Yet, farmers have some information at seeding time; they have estimates of available soil moisture, costs of production and commodity prices. Given this information, farmers must evaluate not only the impact of cropping decisions on this year's cash flows but also its impact on future income and risk patterns for their own risk attitudes and risk bearing ability. Obviously, this is a rather complex process. Accordingly, in order to simplify the decision making process, a set of flexible cropping decision rules (Flexcrop) based on spring soil moisture conditions have been formulated by Weisensel (1988). This paper evaluates both profitability and relative riskiness of flexible and fixed cropping decision rules for Brown and Dark-Brown soil zones of Saskatchewan and makes recommendations as to risk efficient cropping decision rules given differing risk attitudes of farmers.

Cropping Decision Rules

The flexible cropping decision rule is based on available soil moisture at seeding time and expected commodity prices. These decision rules identify a critical soil moisture at spring seeding time (Mc), which is a break-even point. If the available soil moisture is less than Mc, then the farmer would choose to fallow; if the available soil moisture is greater than Mc, then the farmer would crop. The key to this decision rule is the value of spring soil moisture information. If there is measurement error or if yields are relatively independent of seeding time moisture, then the flexible decision rules will have little information value over the alternative decision rule, the fixed crop rotation. Under fixed rotations, the farmer disregards all available soil and price information and follows a strictly defined and rigid cropping rotation and can be viewed as a special case of the flexible cropping rotation where either the spring moisture conditions is relatively stable over time or information associated with spring soil moisture has little economic value--i.e. spring soil moisture has little effect in determining crop decisions. Since the May soil moisture conditions can be divided into relatively few states, the seed or no-seed decision results in a relatively small set of potential strategies associated with the following critical Mc threshold soil moisture levels:

1. 40 mm,
2. 50 mm,
3. 60 mm,
4. 70 mm,
5. 80 mm and
6. 90 mm.

Note that the problem is further complicated when more than one crop can be grown. In this case, after the decision has been made to crop, the actual crop selection is based on the most profitable crop or the crop with highest returns over variable costs. Flexible crop rotations incorporate the following additional constraints:

1. the most profitable crop in the rotation is grown first. If canola is the most profitable crop and has already been allocated to one field, the second most profitable crop is then grown.

2. canola can only be grown once in four years on a particular field. This is mainly because of disease build up on canola fields.

Fixed crop rotation strategies include the following:

1. Wheat-fallow (W-F)
2. Wheat-wheat-fallow (W-W-F)
3. Wheat-wheat-wheat-fallow (W-W-W-F)
4. Wheat-fallow-barley-fallow (W-F-B-F)

5. Wheat-wheat-barley-fallow (W-W-B-F)
6. Wheat-fallow-canola-fallow (W-F-C-F)
7. Canola-wheat-wheat-fallow (C-W-W-F)

Two crops are evaluated in the brown soil zone--barley and wheat and three crops are evaluated in the dark brown soil zone: canola, wheat and barley.

Procedure

Each of the cropping decision rules and strategies are evaluated by simulating their impact on farm net worths over a period of 15 years, assuming stochastic commodity prices, May seeding moisture levels and yields. Input costs are assumed to be known and invariant--riskless. Additional assumptions in simulating farm net worths include

1. there are no yield quotas,
2. there are no deficiency payments and
3. there are no taxes.

The objective function of farmers can mathematically be defined as

$$\text{Maximize NFV} = \sum_{t=1}^{n} [[[\sum_{i=1}^{m} \text{maximize}_{nrt}(((P_{cit} - C_{cit})Y_{cit}) - V_{cit})H_{it}) - R_t - F_t](1+a)^t + I_t] - D_0] \quad (1.0)$$

$$\text{s.t.} \sum_{i=1}^{m} H_{it} = H_o$$

where,
- NFV = net future value,
- n = number of years in the planning period,
- m = number of fields in a particular year,
- maximize_{nrt} = maximize net returns in period t,
- P_{cit} = price per kilogram of crop c in field i at period t,
- C_{cit} = cost per kilogram of yield produced of crop c in field i at period t,
- Y_{cit} = yield in kilograms of crop c for field i in period t,
- V_{cit} = direct per hectare costs of producing crop c in field i at period t,
- H_{it} = number of hectares in field i at period t,
- R_t = machinery replacement fund in period t,
- Ft = family withdrawals incurred in period t,
- a = inflation rate,

I_t = interest payments in period t,
D_0 = initial debt level and
H_0 = total farm size.

Equation 1.0 states that farmers seek to maximize future net worth over time. Future net worth is the compounded net returns less family withdrawals (F_t), machinery replacements fund (R_t) and the future value of beginning debt (D_0). Net returns are defined as gross returns less direct costs times the number of hectares in each field. Direct costs include cost of seed, fertilizer, herbicides, insecticides, fuel, repairs, custom work and insurance. Note that direct costs are expressed as both a per hectare costs, Vcit, which includes seed, fertilizer, tillage fuel and repair costs and per kilogram, Ccit which includes harvesting, transportation and storage fuel and repair costs. Also note that future compounding is accomplished through the interest charge on outstanding debt/accumulated cash reserves (net cash balances). When net cash balances are negative, the farmer is a net borrower and when the net cash balances are positive, the farmer is a net lender. The starting balance is set equal to initial debt (D_0). Finally, optimization is a two-stage maximization process. The first stage is the selection of the optimal crops to be seeded. The second stage is the selection of the optimal fallow/cropping soil moisture threshold.

Each strategy is simulated 1,000 times over a 15 year period and the resulting net future values are annualized and converted into probability functions of annualized income. The corresponding probability functions are subjected to stochastic dominance with respect to a function in order to identify risk efficient strategies[1]. Both the short and long-run scenarios are evaluated. In the short run, it is assumed that machines are fixed and no adjustments can be made. In the long run, machinery replacement costs are part of variable costs per hectare and can be adjusted according to cropping intensity and crops grown.

Data

Yields are based on simulated evapo-transpiration rates (AET) and a random error term. The AET equations are estimated based on Kindersley and Saskatoon weather stations and Innovative Acres and crop insurance data. Evapo-transpiration rates are simulated based on spring soil moisture, random selection of summer precipitation and a random error term. Spring soil moistures is simulated based on August soil moisture, a random winter precipitation and a random error term. Prices are simulated using the Stochastic Top Management program.[2] Two hundred prices were simulated for each commodity. The mean, standard deviation, minimum and maximum values for the commodity price data are provided in Table 1.

Crop production costs are based on the Top Management Workshops (Schoney, 1988). In the short run, Vcit is based on direct cost not including harvesting, transport and storage costs. Direct cost of producing wheat on fallow in the Dark-Brown soil zone is $62.77 per hectare in the short run. In the long run, Vcit is based on variable costs including the short run direct costs, labor, operating capital charges and machinery replacement. Long-run variable cost of

[1] The theoretical basis for Stochastic Dominance with Respect to a function is provided in Meyer (1977a, 1977b). King and Robison (1981) developed a program for the procedure.

[2] Stochastic Top Management program generates distributions of stochastic variables based on normal and triangular distributions and cross correlations. The correlations between prices are observed for each simulation.

producing wheat on fallow in the Dark-Brown soil zone for wheat on fallow is $119.82/hectare (Table 2). Labor and management charges are assumed to be available for family living withdrawals. In the short run, these are set at $18,000 annually for both the Brown and Dark-Brown soil zones. In the long run, family living withdrawals are based on $6,000 (management fee) plus the sum of the variable labor charges. The short-run machinery replacement fund is $18,330 for the Brown soil zone and $17,017 for the Dark-Brown soils and, in the long run is part of the variable expenses and is allowed to readjust to the appropriate cropping intensity. Initial debt levels are set at $100,000 for the Brown soil zone and $126,000 for the Dark-brown soils--which correspond to middle size representative farms of Top Management Data Base.

Table 1: Commodity Prices for Wheat, Barley and Canola.

	Wheat	Barley	Canola
		----- $/kg -----	
Mean	0.14	0.09	0.27
Std dev	0.03	0.02	0.04
Min val	0.09	0.04	0.17
Max val	0.20	0.13	0.39

Table 2: Saskatchewan Crop Production Costs, Brown and Dark-Brown Soils, 1988

Soil	Enterprise	SR Direct Costs	Long Run Costs: Variable Costs	Long Run Costs: Machinery Replacement	Long Run Costs: Total
		($/hectare)			
Brown	Wheat on Fallow	61.93	82.25	37.14	119.39
	Wheat on Stubble	79.95	103.28	30.98	134.26
	Barley on Fallow	65.57	93.99	44.56	138.55
	Barley on Stubble	72.68	95.03	33.47	128.49
	Fallow	11.88	18.69	9.47	28.26
Dark Brown	Wheat on Fallow	62.77	82.67	37.16	119.82
	Wheat on Stubble	86.83	110.58	33.94	144.42
	Barley on Fallow	62.58	84.14	48.33	132.46
	Barley on Stubble	89.39	116.67	41.93	158.60
	Canola on Fallow	81.68	99.19	35.39	134.58
	Canola on Stubble	108.05	133.78	33.05	166.83
	Fallow	11.31	18.54	12.31	30.85

Source: Schoney (1988)

Results

In the following sections, the results are presented in terms of the mean and the standard deviation annualized income. When distributions are normally distributed, these characteristics are sufficient to adequately describe the income risk trade-offs. However, income distributions are seldom normally distributed even when all stochastic variables are assumed to be normally distributed. Thus, a second method of efficient risk sets is used to analyze the results, stochastic dominance with respect to a function.

Analysis of Means and Standard Deviations

There are eleven strategies based on wheat, barley and fallow combinations: six flexible and five fixed crop rotations in the brown soils. In the short run, the most profitable crop rotation is also the most intense and the riskiest--the 40mm Mc, flexible crop rotation which generates a real annualized cash flow mean value of $32,226, a standard deviation of $29,904 and a cropping intensity of 72 percent. Although barley is also an option under the flexible crop rotation strategies, wheat is the only crop grown, as can be expected. The W-F-B-F cropping strategy not only generates the lowest standard deviation--$17,965, but also generates the lowest mean annualized income of -$25,115. In the long run, when machine fixed costs become variable, the profit maximizing decision strategies become more conservative and less intense. In the long run, the most profitable rotation is the 50mm Mc Flexcrop rule. This rule generates an annualized income of $29,668. This cropping strategy has the second highest standard deviation of $26,664, an associated cropping intensity of 66 percent and average wheat yield of 1,405 kg/ha. The W-F-B-F rotation generates the lowest mean real annualized cash flow and standard deviation values (Table 3).

Barley, canola, wheat and fallow are combined to form thirteen strategies: seven fixed and six flexible rotations in the Dark-Brown soils. In short-run, the 40mm Mc flexible cropping strategy also generates the highest mean annualized real cash flow and standard deviation of $56,024 and $26,626, respectively. This rotation has a cropping intensity of 89 percent, featuring 70% wheat and 19% canola. The W-F-B-F rotation generates the lowest mean annualized real cash flow as well as standard deviation values of -$13,704 and $12,003 respectively. As can be expected, when machine replacement charges are treated as variable costs, the long-run profit maximizing strategies are less intense than the short run. The long-run profit maximizing cropping strategy is the 60mm Mc flexible crop rotation which has a real annualized cash flow value of $52,670, a standard deviation of $25,566 and a cropping intensity of 82 percent. The W-F-B-F generates both the lowest mean and standard deviation of real annualized cash flow values of -$6,846 and $11,086 respectively (Table 4).

Risk Efficient Sets

Three groups of farmers are delineated--risk lovers, moderately risk averse and highly risk averse. In the short run, the risk efficient strategies for risk lovers are 40, 50 and 60mm Mc soil moisture levels in the Brown soil zone. The same group of farmers in the Dark-Brown soil zone should consider 40 and 50mm Mc soil moisture levels. Farmers who are classified as moderately risk-averse should consider 40, 50, 60 and 70mm Mc soil moisture levels in the Brown soil zone. The options for this group of farmers in the Dark-Brown soil zones are 40, 50 and 60mm Mc soil moisture levels. Highly risk-averse farmers should consider 70mm Mc soil moisture levels in the Brown soil zone and 60mm Mc soil moisture level in the Dark-Brown soil (Table 5).

In the long run, risk efficient strategies for risk lovers are 50mm and 60mm Mc soil moisture levels in the Brown soil zone and 50, 60 and 70mm Mc in the Dark-Brown soil zone. Moderately risk-averse farmers should have the options of 50, 60, 70 and 80mm Mc soil moisture levels in the Brown soil zone and 60, 70, 80 and 90mm Mc soil moisture levels in the Dark-Brown soil zone. The highly risk-averse group of farmers should consider 80mm Mc soil moisture levels in the Brown soil zone and 90mm soil moisture levels in the Dark-Brown soil zone (Table 5).

The results also indicate the importance of May seeding soil moisture information. The May seeding soil moisture information results in higher real annualized cash flows, yields and lower yield variability than the same cropping intensity under fixed crop rotation strategies. Thus, there are no fixed crop rotation strategies in the efficient set for the short and long-run models and in the Brown and Dark-brown soil zones implying that fixed crop rotations are inefficient.

Table 3: Simulated Real Annualized Cash Flows Cropping Intensity and Yields by Strategy for the Short-Run Model in Brown Soils

Strategy	Short Run Real Annualized Cash Flows Mean	Short Run Real Annualized Cash Flows Std Dev	All Crop Int Mean	Long Run Real Annualized Cash Flows Mean	Long Run Real Annualized Cash Flows Std Dev	All Crop Int Mean
	--$/Year--		--%--	--$/year--		--%--
Fixed Rotations						
W-F	712	21,018	50	3,870	20,884	50
W-W-F	10,762	25,548	67	5,859	25,940	67
W-W-W-F	18,924	26,559	75	9,631	27,269	75
W-F-B-F	-25,115	17,965	50	-26,407	18,363	50
W-W-B-F	2,684	24,380	75	-5,637	24,263	75
Flexible Rotations						
40mm	32,226	29,904	72	27,760	27,755	72
50mm	31,908	29,687	66	29,668	26,664	66
60mm	30,343	29,362	60	28,530	26,496	60
70mm	24,508	28,384	53	27,732	24,129	53
80mm	17,320	28,145	47	25,492	24,033	48
90mm	12,748	27,141	43	19,660	23,173	43

int = intensity

Table 4: Simulated Annualized Real Cash Flows Cropping Intensity and Yields by Strategy for the Short-Run Model in the Dark-Brown Soils

Strategy		Short Run Real Annualized Cash Flows Mean	Short Run Real Annualized Cash Flows Std Dev	All Crop Int Mean	Long Run Real Annualized Cash Flows Mean	Long Run Real Annualized Cash Flows Std Dev	All Crop Int Mean
		-- $/year--		--%--	-- $/year--		--%--
Fixed Rotations							
	W-F	7,741	14,282	50	20,265	13,815	50
	W-W-F	26,327	18,966	67	29,081	19,375	67
	W-W-W-F	33,762	21,180	75	32,614	21,294	75
	W-F-B-F	-13,704	12,003	50	-6,846	11,806	50
	W-W-B-F	15,014	18,775	75	9,756	18,355	75
	C-F-W-F	12,142	14,933	50	25,816	14,544	50
	C-W-W-F	39,200	21,477	75	39,426	21,685	75
Flexible Rotations							
	40mm	56,024	26,626	89	48,753	27,525	89
	50mm	55,750	26,210	86	50,664	26,333	86
	60mm	55,762	25,287	82	52,670	25,566	82
	70mm	52,446	24,306	77	52,134	24,929	77
	80mm	51,061	24,399	73	51,632	23,675	73
	90mm	48,108	23,829	68	50,834	21,824	68

int = intensity

Table 5: Stochastically Efficient Strategies, Brown and Dark-Brown Soils Saskatchewan, by Length of Run

Strategy	Risk Loving				Moderately Risk Averse				Highly Risk Averse			
	Brown		Dark Brown		Brown		Dark Brown		Brown		Dark Brown	
	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
W-F												
W-W-F												
W-W-W-F												
W-F-B-F												
W-W-B-F												
40mm	X		X		X		X					
50mm	X	X	X	X	X	X	X					
60mm	X	X		X	X	X	X	X			X	
70mm				X	X	X		X	X			
80mm						X		X		X		
90mm								X				X

SR = short-run,
LR = long-run,
The corresponding Arrow Pratt risk aversion coefficients are [-0.005,0], [0 - 0.0003] and [0.0003 - 0.005] for risk loving, moderately risk averse and highly risk averse respectively.

Conclusions

First, none of the fixed crop rotation strategies are risk efficient, only the flexible cropping decision rules are risk efficient. This implies that farmers should carefully consider spring soil moistures in their cropping decisions. Allowing cropping decisions to be flexible is an important advantage regardless of producer risk attitudes. Secondly, varying producer risk attitudes can be incorporated by careful selection of the critical or break-even spring soil moisture. In this study, profit maximizers should consider spring soil moistures somewhere around 40 to 50mm, depending upon their machinery capacity. This corresponds to cropping intensities of 66 to 72% in the brown soil zones and 86 to 89% in the dark brown soils. Risk averters should incorporate more caution in their assessment of cropping decisions by raising their own personal spring soil moisture thresholds. Depending upon their personal levels of risk aversion, they might consider spring soil moistures of 60 to 70 mm which corresponds to cropping intensities of 53 to 60% in the brown soils and 77 to 82% in the dark brown soils. The latter recommendations would be considered the "traditional" extension recommendations. Finally, these results indicate that there is no appropriate, universal cropping recommendation for Saskatchewan farmers in the Brown and Dark-Brown soil zones. Extension personnel should carefully analyze farmers' risk attitudes as well as taking into account, soil zone and machinery sizing in making cropping recommendations, Likewise, policy makers and researchers should also consider risk attitudes in designing and evaluating farm support programs and predicting farmers responses.

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