RISK AND CROP ROTATIONS IN SASKATCHEWAN[1]

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Introduction

Spring wheat and fallow have dominated land use practices in Saskatchewan accounting for approximately 34 percent and 40 percent of the total crop land use respectively. However the proportion of cropland devoted to fallow has decreased while that of spring wheat has increased since 1980 (Table 1). Soil scientists have long urged producers to reduce fallow acreage due to the known loss in soil organic matter and increased risk of soil erosion resulting from the practice (Saskatchewan Agricultural Services Co-ordinating Committee {SASCC}). In addition, crop scientists have developed several new varieties of other grains, oilseeds and specialty crops thus allowing producers to diversify production (SASCC). Farm business management specialists have shown the benefits of reduced fallow acreage and the increased net income that can be realized from crops other than spring wheat (Zentner et al. and Saskatchewan Agriculture 1980-84). Yet, producers, for the most part, persist with rotations dominated by fallow and spring wheat although as indicated in Table 1, their selection patterns are changing over the longer run. The purpose of this paper is to investigate the influence of production and marketing risk on the use of fallow in rotation choice thereby giving some insights into this phenomena.

Saskatchewan producers, in general, continue to grow spring wheat and a variety of other crops but employ different amounts of fallow depending on the soil zone in which they are located. Fallow continues to be used extensively throughout the Brown soil zone. Its use has been reduced in the Dark Brown and Black zones but it still accounts for a significant portion of the land use (Table 2). Producers in the Dark Brown and Brown soil zones fallow to conserve moisture and reduce the risk of crop failure in dry years (SASCC). Producers in the Black soil zone fallow in part to control weeds (SASCC). Saskatchewan farmers seem to perceive that the shorter run reduction in production risks by fallowing overcomes the longer run increase in production risk from loss of organic matter and soil erosion. In addition, low Canadian Wheat Board (CWB) delivery quotas have made many producers consider fallow or non CWB regulated crops in order to reduce on-farm inventories (CWB and Saskatchewan Agriculture). Perhaps if the above outlined production and marketing risks associated with various crop rotations are included in the analysis the results will more closely parallel actual producer

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1 Adapted from "A Risk Efficiency Analysis of Crop Rotations in Saskatchewan" by W.J. Brown.

Table 1: Percentage of Saskatchewan Crop Land in Fallow, Spring Wheat, and Other Crops, 1971-85

Crop Year	Fallow	Spring Wheat*	Other Grains*	Flax & Canola*	Other
1971	39	26	24	8	2
1972	44	27	22	5	3
1973	41	31	20	5	3
1974	42	28	21	5	4
1975	42	29	21	6	2
1976	43	35	18	4	1
1977	43	35	17	8	0
1978	41	33	18	12	0
1979	41	36	15	16	0
1980	42	36	17	10	0
1981	38	36	20	6	2
1982	37	38	19	6	2
1983	36	40	16	8	2
1984	34	38	18	10	3
1985	32	38	19	8	3
Average	39.7	33.8	19	7.8	1.8

Source: Saskatchewan Agricultural Statistics 1985.

* Percent includes crop grown on both fallow and stubble.

behavior with respect to the amount of fallow used in chosen crop rotations.

The gross margins per acre for a number of crops grown in Saskatchewan were calculated from 1971 to 1985. Gross margins as used in this analysis is defined as price times yield minus direct cash costs. Gross margins are calculated for each crop grown on land fallowed the previous year and again for the same crop grown on stubble. These gross margins for each crop, are then compared with that of spring wheat on fallow in order to calculate the amount of correlation between them. The correlation coefficients are used to designate which crops will add diversity and thereby spread risk if included in rotations which already contain spring wheat and/or fallow. Using this criteria as a basis 24 fixed rotations are synthesized and the gross margins over the historical period for each of these is calculated. These rotation gross margin time series are in turn analyzed for their relative risk efficiency. The resulting risk efficient sets of rotations are compared with each other and actual producer behavior.

Table 2: The Percentage of Saskatchewan Crop Land in Fallow, and Spring Wheat, by Crop District, 1976 and 1981

	Fallow	Spring Wheat
Wet Black (CD#9)		
1976	32	23
1981	26	28
1985	13	34
Dry Black (CD#8)		
1976	32	33
1981	24	37
1985	18	27
Dark Brown (CD#6)		
1976	41	37
1981	39	39
1985	32	43
Brown (CD#3)		
1976	44	32
1981	44	30
1985	44	31

Source: Statistics Canada.

Theoretical Background

The most commonly used criterion for measuring relative risk efficiency is the mean-variance trade-off. When dealing with net income, those alternatives exhibiting the lowest variance of net income for given levels of expected net income, or conversely the maximum level of expected net income for given levels of variance of net income, are said to be on the risk efficiency frontier of risk neutral and risk averse decision makers. The mean-variance trade-off has both strengths and weaknesses. It is an effective means of summarizing data and identifying alternatives having the greatest expected value of a variable for a given level of variance of that same variable. However, in order for it to be technically correct the net income must be normally distributed or the decision maker's utility must only be a function of mean (expected net income) and variance. Distributions of alternative net income exhibiting skewness and higher moments are common in agricultural situations (Barry, p. 73). The risk averse decision maker may choose an alternative that is not on the risk efficiency frontier when these additional characteristics of the distribution of outcomes are considered. Therefore, risk efficiency criteria that consider the total distribution of outcomes rather than one or two summary statistics are preferred.

Stochastic efficiency criteria consider the total distribution of net returns. They are most useful in situations involving: a single decision maker whose utility function is unknown, several decision makers whose utility functions differ yet conform to a set of restrictions (eg. risk averse), and in analyzing policy alternatives or (as in the present case) extension recommendations that affect many diverse individuals (Barry, p. 69). As the degree of stochastic efficiency increases the restrictive assumptions on the decision maker's utility function also increase while it is hoped the number of efficient alternatives from which to choose decreases. First degree stochastic efficiency (FSE) assumes decision makers prefer more to less; that is, they have positive marginal utility of income. A risky alternative dominates others by FSE if its cumulative distribution function (CDF) lies entirely to the right when plotted with probability on the vertical axis and expected gross margin on the horizontal axis (Figures 1 and 2) (Quirk and Saposnik, and Fishburn in Anderson et al., Zentner et al.). Second degree stochastic efficiency (SSE) assumes decision makers are risk averse, that is, they have positive but decreasing marginal utility of income. A risky alternative dominates others by SSE if of its CDF is to the right more often than the others (Figures 1 and 2) (Fishburn, Hanoch and Levy, Hader and Russell, and Hammond in Anderson et al., and Zentner et al.). Third degree stochastic efficiency (TSE) builds on the assumptions of FSE and SSE and further assumes that decision makers exhibit decreasing risk aversion as they become wealthier. A risky alternative dominates by TSE if its CDF is to the right more often and at lower income levels than the others (Figures 1 and 2) (Whitmore, and Hammond in Anderson et al.and Zentner et al.).

The Data

Gross margins from 1971 to 1985 were calculated for the fallow enterprise (that is, the cost of fallowing) and for the following crops, on both fallow and stubble, by soil zone; spring wheat, barley, oats, fall rye, flax, and lentils. Gross margins for canola and peas on fallow and stubble were calculated for all soils except the Brown soil zone. Gross margins for durum wheat on fallow and stubble were calculated for the Brown and Dark brown soil zones only.[1]

The first component in a crop gross margin is output price. Farm price was used for all crops other than spring wheat. The spring wheat price is calculated as follows: the initial payment received each year from the Canadian Wheat Board (CWB) for #1, 2, 3, and Feed grades of red spring wheat were reduced by charges for transportation to the terminal point, country elevation, and removal of dockage for each year. The final payment received from the CWB for each grade each year was added to the adjusted initial price for the following year to account for the time lag in final payments. This adjusted

[1] Refer to Brown and Forsberg for more detail on data construction.

Figure 1: CDF's Rot'ns 1,6 & 24 Wet Black Soil

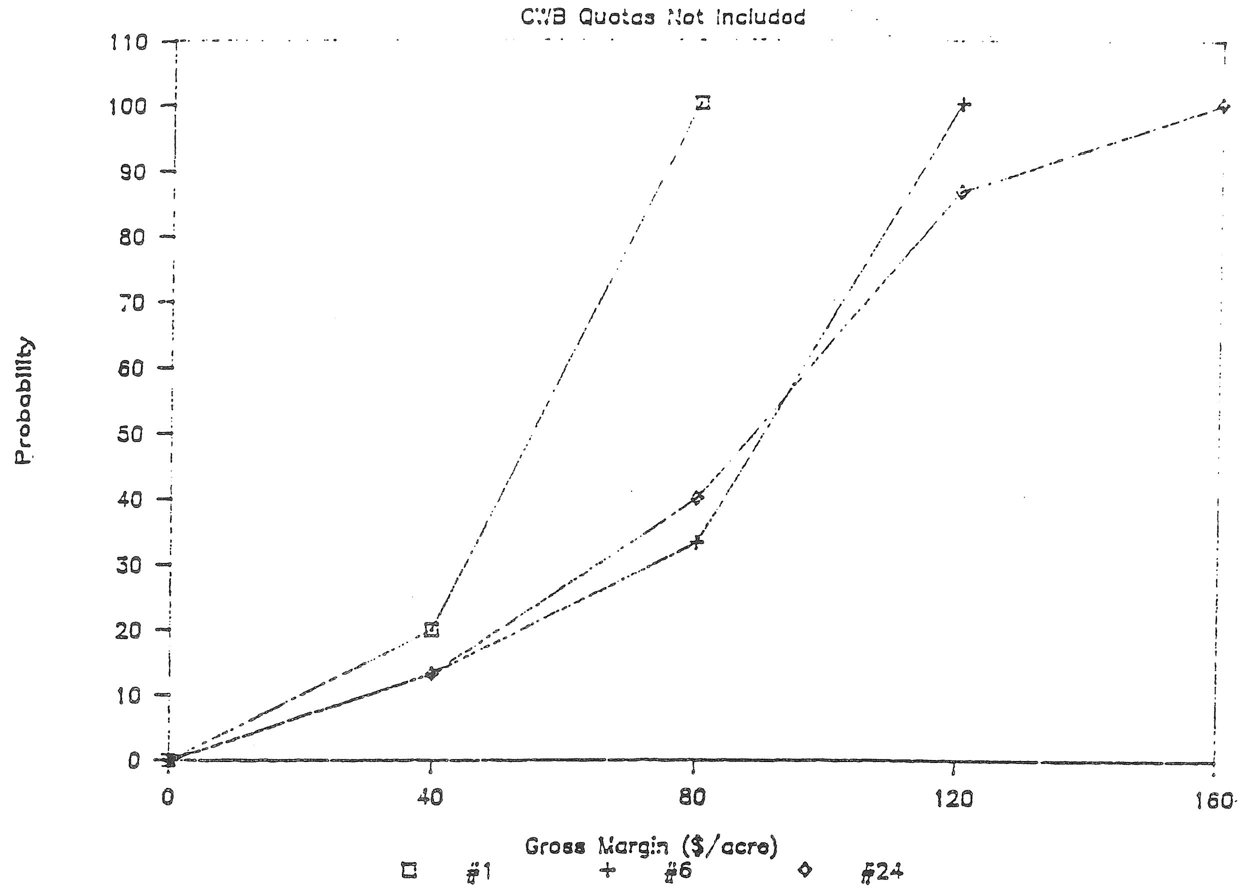
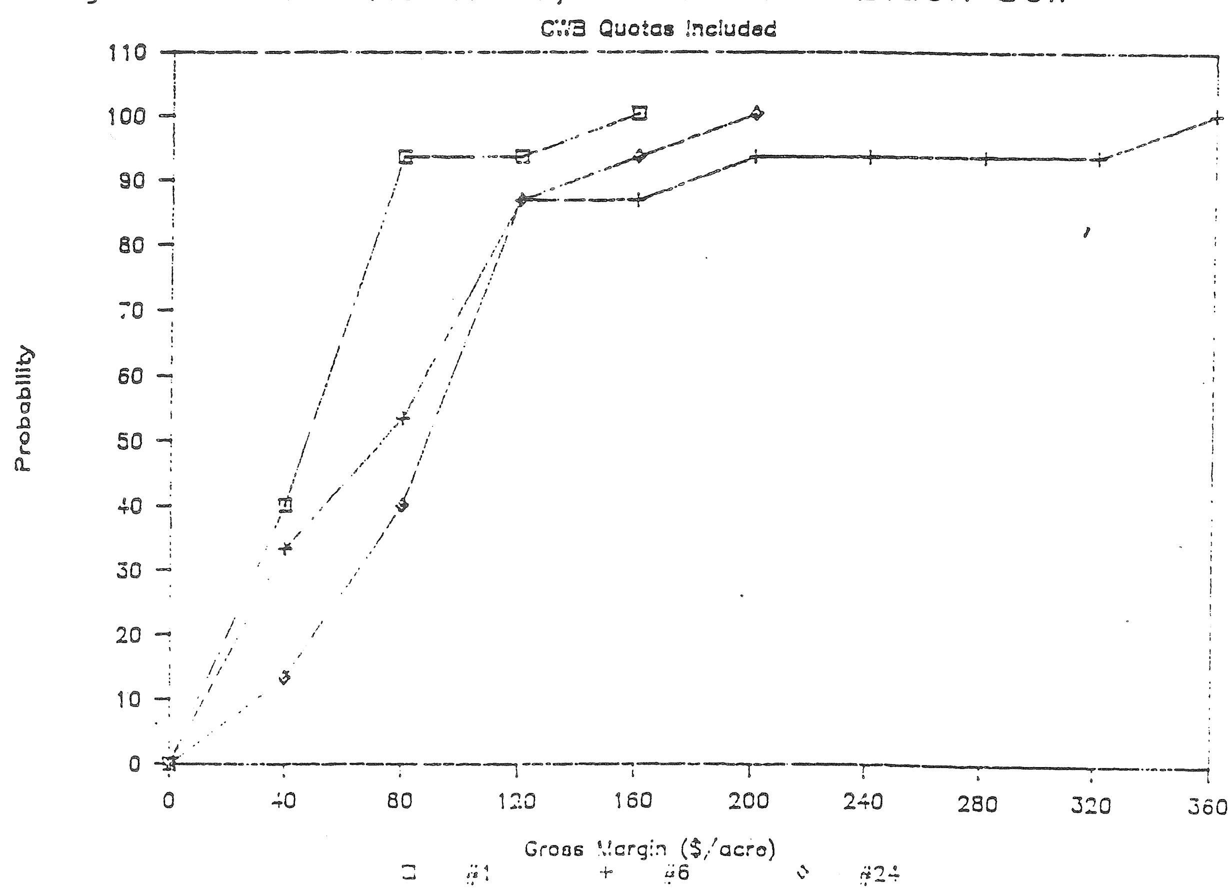


Figure 2: CDF's Rot'ns 1,6 & 24 Wet Black Soil



price received by farmers for each spring wheat grade was further adjusted to reflect the percentage of each grade marketed in each of the soil zones. The percentage of grade marketings by soil zone were taken from representative crop districts: #3 (Brown), #6 (Dark Brown), #8 (Dry Black), and #9 (Wet Black) (Ulrich and Furtan). The final result is a weighted farm price received for spring wheat for each of the four soil zones.

The second component in calculating a crop gross margin is yield. Soil zone yield data for the crops on both fallow and stubble were based on Saskatchewan Crop Insurance Corporation risk areas: #3 (Brown), #12 (Dark Brown), #17 (Dry Black), and #21 (Wet Black). Separate fallow and stubble yield data for 1971 and 1972 were not available, so the average yield for those years was adjusted by the relationship between fallow and stubble yields established through 1973 to 1985. Lentil and pea yields were supplemented by information from the Saskatchewan Agriculture Specialty Crop Reports (Saskatchewan Agriculture 1980-1984).

The final component needed in the calculation of crop gross margins are the direct cash costs which are subtracted from gross income. Direct cash costs were assumed to be the direct operating costs of machinery power and repair and crop materials and these were obtained from the Farmlab publication entitled "1985 Costs of Producing Crops and Forward Planning Manual for Saskatchewan" (Schoney). This publication is based on the detailed costs from some 60 farmers from each of the main soil zones in Saskatchewan and although it is not a random sample it is the best estimate of actual production costs presently available in published form. Fallow and stubble cash costs were not available for all crops in each soil zone. Procedures used to estimate these costs are outlined in Brown and Forsberg. These 1985 cash costs were deflated for the period 1971 to 1984 using an index based on the amount expended each year in Saskatchewan on: petroleum, diesel oil and lubricants (machinery power and repair), and fertilizer and other crop expenses (crop materials) (Saskatchewan Agriculture 1986). This index represents inflationary price trends and the shift in agricultural technology between 1971 and 1985 and allows for increased use of fertilizer and chemicals on all crops. Its weakness is that it includes the shift away from fallow and thereby over adjusts the cash costs, particularly of stubble crops. A second indexing procedure based on the farm input price index for: machinery and motor vehicle operation and petroleum products (machinery power and repair), and crop production expenses (crop materials) was also used (Saskatchewan Agriculture 1986). The results based on this second index were similar and are reported in Brown and Forsberg.

The above method of calculating crop gross margins over time is not ideal. A random sample of producers keeping detailed enterprise records is preferable but is not available. Since costs were deflated by two methods based on rather different assumptions with the results not changing significantly the approach adopted appears satisfactory. However, no direct relationship between increased expenditures on inputs (fertilizers and chemicals) and increased yields is accounted for. However, the relationship between increased input use and increased yield should be accounted for in the cost and yield data since these data are based on actual producer behavior.

Given the above, gross margins for a number of hypothetical rotations for the period 1971 to 1985 are calculated. Portfolio theory specifies that individual components within a portfolio exhibiting high positive correlation add to the risk or variance of the portfolio. Gross margins for each of all crops, both fallow and stubble, and within each soil zone, were compared with that of wheat on fallow by soil zone. The correlation coefficients for each crop by soil zone are shown in Table 3. For simplicity the objective was to have the fixed rotations include only one representative from the grain, oilseed and specialty crop categories. Wheat on fallow and stubble was chosen as the grain because of its dominant acreage in the province. Barley, oats, fall rye and durum wheat, on both fallow and stubble, were eliminated from all rotations on all soil zones due to their high correlation coefficients. Canola was chosen over flax as the oilseed representative in the rotations for all soil zones other than Brown due to its lower correlation coefficient and its greater acceptance by farmers in the past. Lentils was chosen over peas as the specialty crop representative in the rotations for all soil zones due to its lower correlation coefficient.

The rotations as selected are fixed for the period 1971 to 1985 and are shown in Table 4. These rotations were assumed to contain either wheat or canola and no more than 30 percent lentils. The effect on the level and variance of gross margin of reducing fallow intensity and diversifying into canola (oilseeds) and/or lentils (specialty crops) may be calculated by comparing these variables for the other 23 rotations with that of rotation #1; 50 percent wheat on fallow and 50 percent summerfallow.

In the calculation of the rotation gross margins several points should be noted. First, the weightings of the crops in each rotation have been kept constant over time because the objective was to compare the distributions of gross margins from fixed rotations. One or several other rotations in which individual crop weightings change from year to year may well dominate the rotations outlined in Table 4. Second, the wheat and canola yields in rotations which include lentils have not been adjusted to compensate for the nitrogen fixing ability of lentils. This benefit to following crops has not been documented in the literature and may be off set by the increased chances of weed problems in lentils and crops following lentils (Slinkard and Drew). Third, crop insurance premiums and payments have not been considered. Crop insurance covers the downside risk of poor years on a crop specific basis for an entire farm. Its effect on the distribution of rotation gross margins on a per acre basis would be difficult to measure and would have to be separated from the effect of C.W.B. quotas. Finally, Western Grain Stabilization Agreement (WGSA) payments were not included in the calculations. The magnitude of per acre WGSA payments are only

Table 3: Correlations of Wheat on Fallow Gross Margins with Alternate Crops by Soil Zones, 1971-85

	Soil Zones			
Wheat on Fallow	BROWN	DARK BROWN	DRY BLACK	WET BLACK
Fallow	-0.23	-0.47	-0.43	-0.47
Wheat on Stubble	0.84	0.89	0.95	0.93
Barley on Fallow	0.90	0.75	0.92	0.88
Barley on Stubble	0.73	0.53	0.89	0.85
Oats on Fallow	0.78	0.56	0.88	0.80
Oats on Stubble	0.65	0.31	0.73	0.62
Durum on Fallow	0.92	0.82	NSE	NSE
Durum on Stubble	0.69	0.77	NSE	NSE
Canola on Fallow	NSE	0.46	0.52	0.58
Canola on Stubble	NSE	0.48	0.46	0.58
Fall Rye on Fallow	0.69	0.70	0.66	0.61
Fall Rye on Stubble	0.76	0.25	0.42	0.50
Flax on Fallow	0.58	0.79	0.75	0.69
Flax on Stubble	0.34	0.47	0.63	0.65
Lentils on Fallow	0.44	0.32	0.16	0.41
Lentils on Stubble	0.43	0.13	0.16	0.26
Peas on Fallow	NSE	0.40	0.38	0.52
Peas on Stubble	NSE	0.49	0.35	0.44

NSE: Represents no such enterprise.

marginally crop rotation specific, that is, they are based on total marketings and are subject to a ceiling. They were made in only four of the fifteen years in the period analyzed (Saskatchewan Agriculture 1986).

The effect of CWB quotas on the rotation gross margins were calculated. The CWB quotas for wheat and canola (flax in the Brown soil zone) were gathered from CWB annual reports for the 1971-1985 time period. Quotas were adjusted to account for the level of delivery allowed for all grades of wheat and canola. That is, if one grade of wheat had an open quota and another only 10 bushels per quota acre, the wheat quota that crop year was calculated as 10 bushels per quota acre. A quota acre was considered to be the same as a rotation acre, that is, it included that portion of the rotation acre either seeded to the crops considered (including lentils) or fallowed; perennial forage was not included. The CWB 'Bonus Acres' program was included in the calculation from 1982 to 1985. In years when the production of one crop from a particular rotation was above its quota level and the production of another crop in the same rotation was less than its quota level; quota allocations were adjusted accordingly to allow for the maximum delivery of all crops. Production above the quota level

Table 4: Twenty-four Hypothetical Crop Rotations Showing Percentage of Each Crop In Each Rotation, All Soil Zones, 1971-85

Rotation	Fallow	Wheat/f	Wheat/st	Canola/f[a]	Canola/st	Lentils/f	Lentils/st
1	50	50					
2	40	40	20				
3	30	30	40				
4	20	20	60				
5	10	10	80				
6			100				
7	50			50			
8	40			40	20		
9	30			30	40		
10	20			20	60		
11	10			10	80		
12	50	25		25			
13	40	20	10	20	10		
14	30	15	20	15	20		
15	20	10	30	10	30		
16	10	5	40	5	40		
17			50		50		
18	50	25				25	
19	40	20	10			20	10
20	50	16.7		16.7		16.7	
21	40	13.3	6.7	13.3	6.7	13.3	6.7
22	30	10	13.3	10	13.3	10	13.3
23	20	6.7	20	6.7	20	6.7	20
24	10	3.3	26.7	3.3	26.7	3.3	26.7

[a] Flax is substituted for canola in the Brown Soil Zone.

was stored at no cash cost and sold when the quota level permitted. This adversely affected rotation gross margins in low quota years and greatly increased them in subsequent years when quotas eventually increased or became open. This method of calculation is a valid measure of the variability of cash flows (gross margins) resulting from following the 24 fixed rotations in Saskatchewan during the time period.

For these fixed rotations a CDF of gross margins was constructed by using order statistics assuming that each gross margin in the time series was separated from its closest neighbors by equal probabilities and there was no probability of receiving higher than the highest (Anderson, et al., p. 42). That is to say, there was a 6.7 percent chance of receiving a gross margin as low or lower than the lowest, a 13.4 percent chance of receiving a gross margin as low or lower than the second lowest, and so on.

The Analysis and Results

The frequency distributions of the rotation gross margins were then compared with each other, through first, second, and third degree stochastic dominance (Table 5). The analysis was completed without the effect of CWB quotas and again with their effect on rotation gross margins included.

The FSE, SSE and TSE sets with the effects of CWB quotas not considered contain on average 40, 9, and 8 percent respectively of the original 24 rotations. The FSE sets for the Dark Brown and Brown soils zones are too large and diverse in rotation type and are not discussed. The FSE set for the wet Black soil zone contains rotations with little or no fallow. The FSE set of the dry Black soil zone is similar to the wet Black soil zone but also includes two rotations with 40 and 50 percent fallow and more than 25 percent lentils. The SSE and TSE sets for the wet and dry Black soil zones are smaller and almost identical. The fallow percentage in the chosen rotations increases dramatically when moving from the Black (3 percent and 0 percent) through the Dark Brown (15 percent) to the Brown (50 percent) soil zone (Table 6).

The FSE, SSE and TSE sets when the effects of CWB quotas are considered contain on average 64, 19, and 8 percent respectively of the original 24 rotations. The FSE sets for all soil zones and the SSE for the two Black soil zones are too large and diverse in rotation type and are not discussed. The SSE and TSE sets are considerably smaller and almost identical in the Dark Brown and Brown soil zones. The rotations in these sets for the Brown soil zone contain 40 and 50 percent fallow, with the remainder evenly distributed between wheat and lentils. The SSE and TSE sets for the Dark Brown soil zone contain 10 and 20 percent fallow, with the remainder evenly distributed between wheat, canola and lentils. The TSE for the dry Black soil zone contains rotations with 10, 20, and 30 percent fallow with the remainder in canola. Rotations with more than 50 percent canola may not be agronomically sound, however, their choice in the risk efficient set is indicative of the competitiveness of canola in the Black soil zone. The TSE for the wet Black soil zone contains rotations with 10 and 20 percent fallow, with the remainder evenly distributed between wheat, canola, and lentils. The fallow percentage in the chosen rotations increases for the two Black soils zones but remains the same in the Dark Brown and Brown soil zones when the effects of CWB quotas are considered (Table 6). Fallow percentage in the TSE set after CWB quotas are included for all soil zones except the Dark Brown are very close to actual percent fallow used by producers (Table 2).

The CDFs of three rotations: #1(50 percent wheat on fallow and 50 percent fallow), #6(100 percent wheat on stubble and #24(a diversified rotation of fallow, wheat, canola and lentils) in the wet Black soil zone are plotted without (Figure 1) and with (Figure 2) C.W.B. quotas

Table 5: Stochastic Efficient Sets by Soil Zone

	Rotation Gross Margins (Not Affected by CWB Quotas)	Rotation Gross Margins (Adjusted for CWB Quotas)
Wet Black		
TSE[a]	6,17,24	23,24
SSE[b]	6,17,24	9,10,11,22,23,24
FSE[c]	6,11,17,24	2,3,4,5,6,7,8,9,10,11,13, 15,16,17,22,23,24
Dry Black		
TSE	6,17	9,10,11
SSE	6,17	5,6,9,10,11,16,17,24
FSE	6,11,17,18,19	1,2,3,4,5,6,9,10,11,14,15, 16,17,18,19,22,23,24
Dark Brown		
TSE	23,24	23,24
SSE	23,24	23,24
FSE	10,11,13,14,17,19, 21,22,23,24	11,12,13,19,22,23,24
Brown		
TSE	18	18
SSE	18,19	18,19
FSE	1,2,3,4,5,6,10,11, 12,15,16,17,18,19, 20,21,22,23,24	1,3,4,5,6,10,11,12,13,14 15,16,17,18,19,20,22,23,24

[a] Third Degree Stochastic Efficient Set

[b] Second Degree Stochastic Efficient Set

[c] First Degree Stochastic Efficient Set

included in the gross margin calculation. These rotations were chosen because they represent extremes in the 24 fixed rotations. In both figures it can be seen that rotation #1 is not in the FSE set, that is the other CDF's are entirely to its right. Figure 1 demonstrates that when C.W.B. quotas are not included rotations #6 and #24 do not dominate each other by either SSE or TSE (Table 5) because the area in which #6 dominates #24 (between $40/acre and $95/acre) is overridden by the area in which #24 dominates #6 (between $95/acre and $160/acre) even with decreasing risk aversion (TSE). However, when C.W.B. quotas are

Table 6: Percentage of Land Use by Soil Zone Based on TSE Set

	Fallow	Wheat/f	Wheat/st	Canola/f[a]	Canola/st	Lentils/f	Lentils/st
Wet Black							
C.W.B. Quotas Not Included	3	1	59	1	26	1	9
Adjusted for C.W.B. Quotas	15	5	23	5	23	5	23
Dry Black							
C.W.B. Quotas Not included	0	0	75	0	25	0	0
Adjusted for C.W.B. Quotas	20	0	0	20	60	0	0
Dark Brown							
C.W.B. Quotas Not Included	15	5	23	5	23	5	23
Adjusted for C.W.B. Quotas	15	5	23	5	23	5	23
Brown							
C.W.B. Quotas Not Included	50	25	0	0	0	25	0
Adjusted for C.W.B. Quotas	50	25	0	0	0	25	0

[a] Flax is substituted for canola in the Brown Soil Zone.

included in the analysis rotation #24 dominates #6 by SSE and thereby TSE (Table 5) because the area in which #24 dominates #6 (between $0/acre and $120/acre) is greater than the area where #6 dominates #24 (between $120/acre and $360/acre).

The mean variance trade-off of the various rotation gross margins, adjusted for CWB quotas, by soil zone is shown in Figures 3-6. The risk efficiency frontier consists of a line connecting rotations that demonstrate the highest levels of mean gross margin for given levels of variance of the same measure. The risk efficiency frontier drawn in the figures is a visual estimate of the true frontier and there may be other rotations that are more efficient than the 24 plotted in the figures. However, no rotations would be above and to the left of this.

The purpose is to see which rotations are on or close to the risk efficiency frontier.

The rotations observed on or close to the risk efficiency frontier are presented in Table 7 with those not in the SSE highlighted by and asterisk (*). The results in Table 7 are significantly different to those in Table 5. The number of selected rotations in Table 7 are significantly more than in the SSE set for all soil zones, except the dry Black zone. Thus, the SSE criteria in this case is more effective in reducing the choice set. In addition, the rotations in Table 7 generally include more fallow than those in Table 5.

Conclusions

Stochastic efficiency criteria show potential in describing producer behaviour with respect to crop rotation choice. The SSE and TSE sets included rotations with increasing proportions of fallow when moving from the Black through the Dark Brown to the Brown soil zone. This is a reasonable representation of actual producer behaviour (Tables 2 and 6). The inclusion of the effects of CWB quotas influences the type of rotations in the SSE and TSE sets for the wet and dry Black soil zones; specifically more fallow is included. Producer behavior has confirmed both the above strategies as a way of coping with both the production and marketing risks involved in farming.

Table 7: Rotations On or Close to the Risk Efficiency Frontier by Soil Zone, (Rotation Gross Margins Adjusted for CWB Quotas)

Wet Black	-	12*,7*,13*,18*,8*,9,10,23,11,24
Dry Black	-	12*,7*,13*,8*,9,,23*,24,10,11,17
Dark Brown	-	12*,20*,21*,22*,23,24
Brown	-	12*,13*,20*,21*,18

* not in SSE

Figure 3: Wet Black Mean Variance Trade-Off

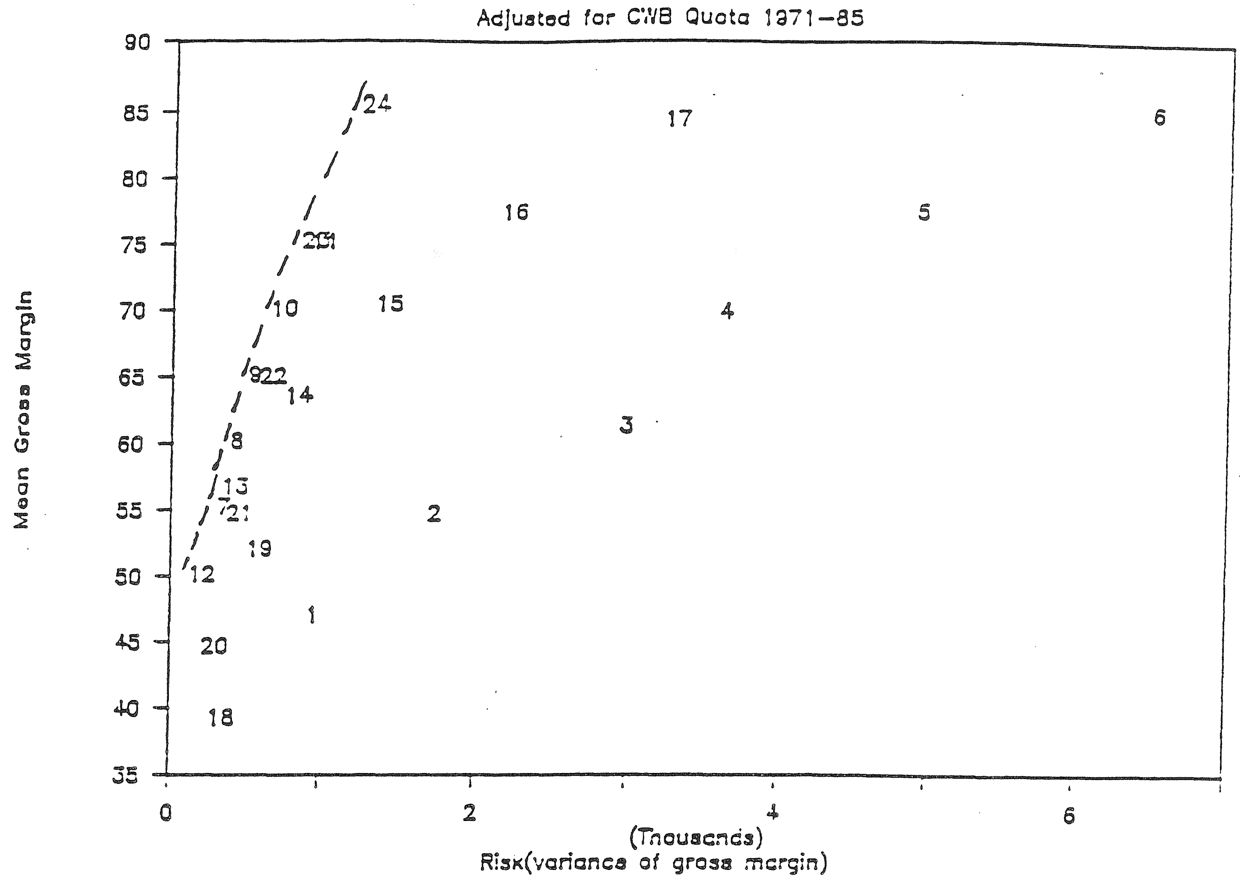


Figure 4: Dry Black Mean Variance Trade-Off

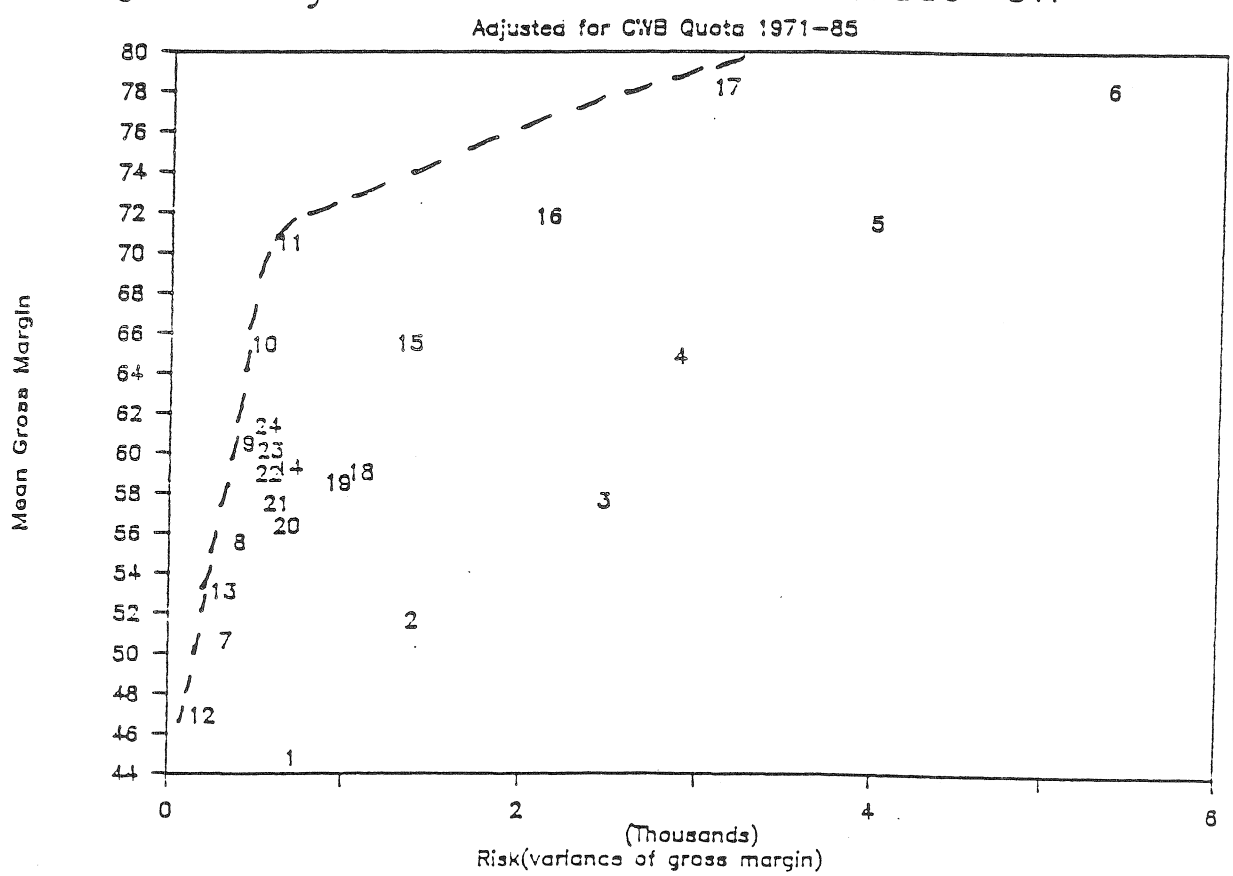


Figure 5: Dark Brown Mean Variance Trade-Off

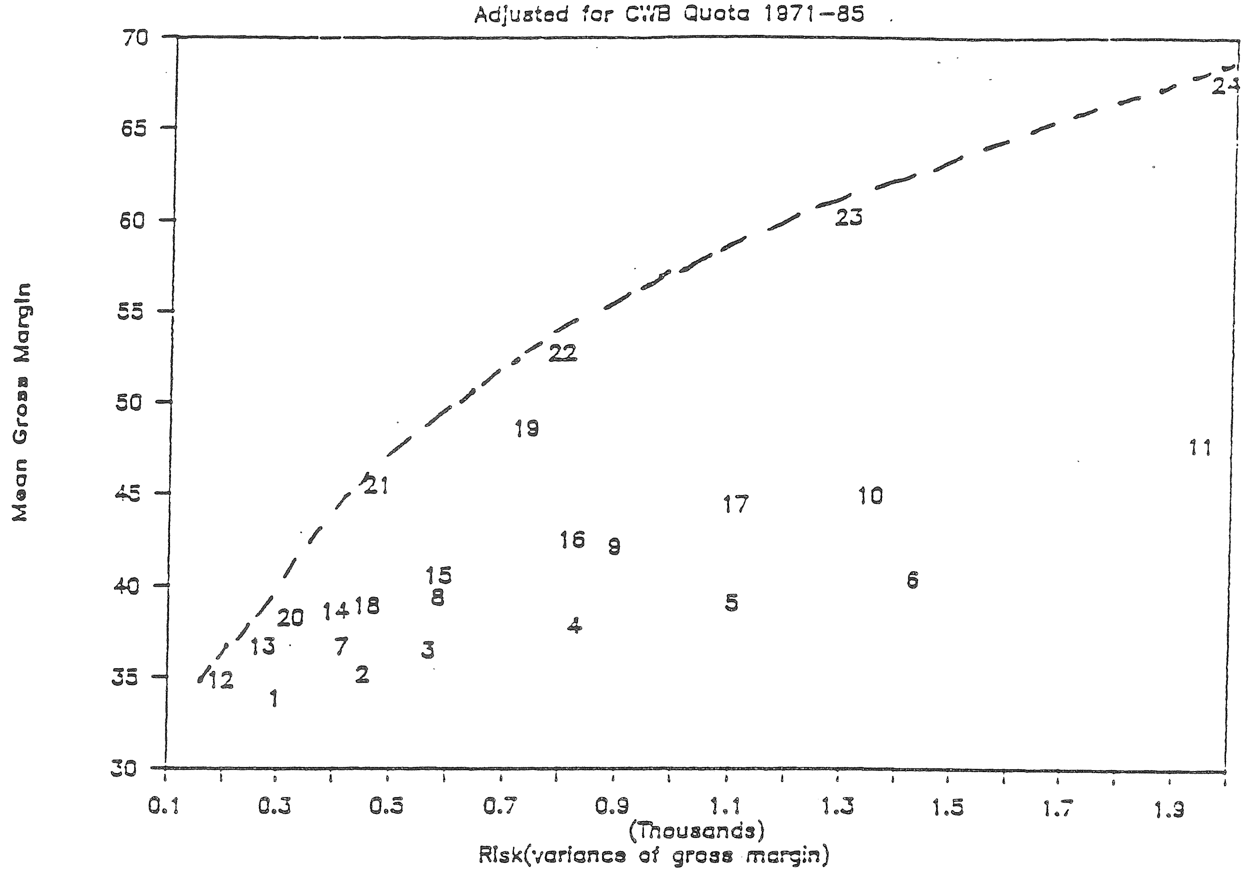
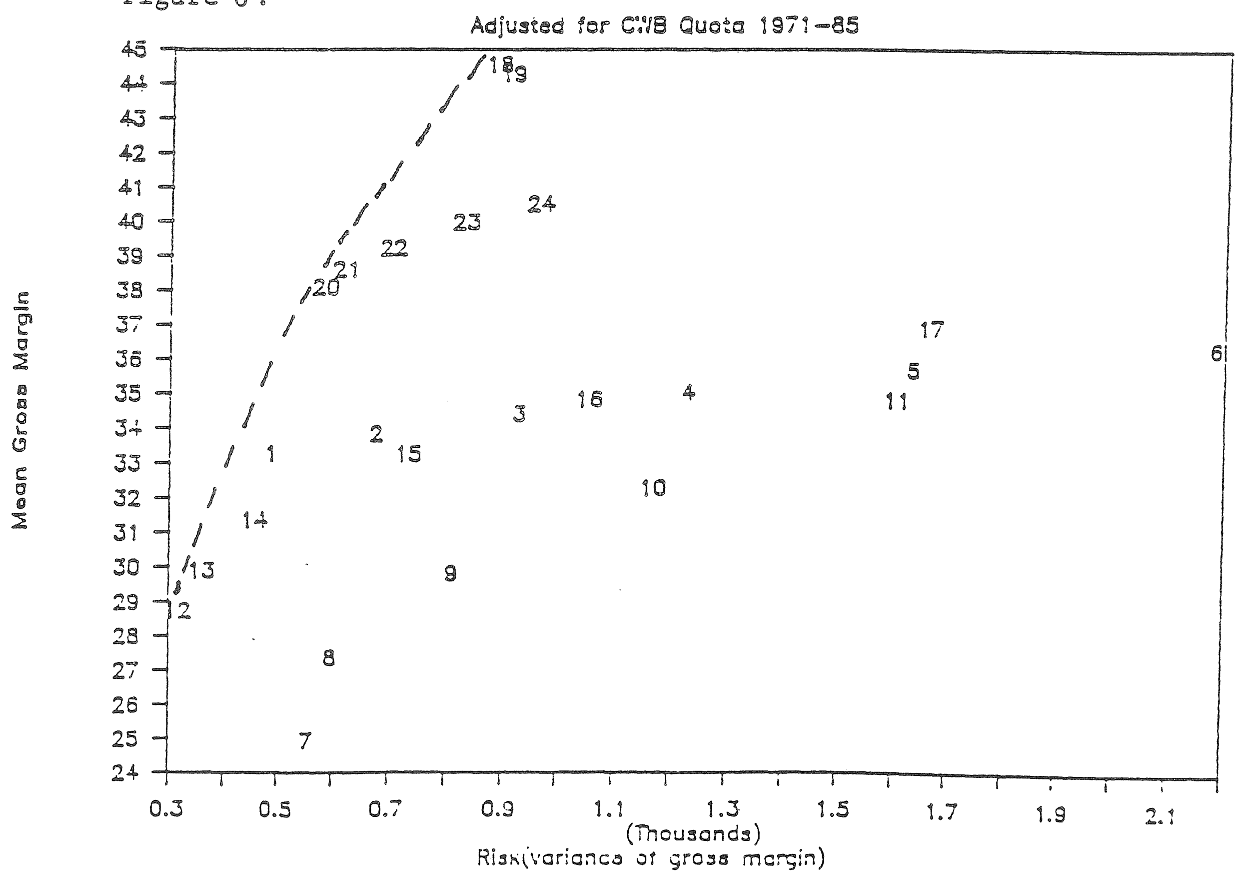


Figure 6: Brown Mean Variance Trade-Off



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