The Impacts on Mean and Variance of Returns-Over-Variable-Costs of Adding Chickpeas to a Traditional Dryland Crop Rotation[1]

Executive Summary

This paper provides producers, policy-makers, researchers, and others a mechanism to assess the effects on economic returns and diversification from the introduction of chickpeas into a Northeast (NE) Montana spring wheat/fallow based rotation. Our simulation estimates distributions for the net returns for each crop in the rotation, and also combines these individual crop returns into returns for an entire farm. Our representative farm consists of 1,500 acres with machinery, labor, and management complements comparable to an average farm in the region.

We consider four different crop rotations, each with a three year cycle. All of the rotations have spring wheat in the first year and fallow in the third year. In the second year, barley is included in the first rotation, desi chickpeas in the second rotation, large kabuli chickpeas in the third rotation, and spring wheat recrop in the fourth rotation.

We use historical data to estimate wheat and barley yield and price distributions. Because chickpeas are a relatively new crop in Montana, yield and price data are more difficult to obtain. A lengthy time series is preferable for estimating yield, price, and correlation distributions. Therefore, we information from an international chickpea price series, Canadian yield data, NE Montana producer surveys, and plot data specific to the region. The resulting chickpea price and yield distributions are then used with those for wheat and barley in our rotation simulations.

The simulation results show that adding desi chickpeas into the simulated rotations provides a slightly higher per acre mean return-over-variable-cost (ROVC) and a lower ROVC variance than the rotation that includes wheat recrop. The wheat/barley/fallow rotation has a relatively low mean ROVC along with a low variance. The rotation including large kabuli chickpeas offers a slightly larger mean

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ROVC (less than $1 per acre) over the rotation with desi chickpeas, but with a substantially higher variance.

The rotation that includes large kabuli chickpeas presents a higher risk/higher reward option. This higher risk stems from additional production risk and marketing risks. We also find that the agronomic benefits to wheat production from the inclusion of large kabuli chickpeas would have to by quite large (almost a 19% yield increase) for this rotation to dominate the spring wheat recrop rotation.

The inclusion of desi chickpeas could be thought of as a proxy for the production of a variety of specialty crops produced in NE Montana. Thus, this cropping system approximates many of the actual production systems being employed in NE Montana. In addition, our simulations show that producers are more likely to diversify their whole farm net income by dedicating relatively small shares of cropland to specialty crops. In fact, that is typically the strategy used by producers.

We clearly show that the addition of a new crop into an existing farm business is neither a necessary nor sufficient condition for income diversification.

I. INTRODUCTION

It is often assumed that adding a new crop into a traditional crop rotation is a diversification strategy. Certainly, adding a crop to a traditional dryland rotation in Montana and North Dakota (or Northern Plains) increases the diversity of crop enterprises. However, such an activity may or may not result in **income diversification**. Income diversification refers to reducing income risk without incurring reductions in income. Thus, adding an enterprise to an existing farm business is neither a necessary nor sufficient condition for risk reduction. Certainly, agronomic advantages may occur from crop rotations. For example, seed potatoes are produced on a parcel of land only once in five to seven years to obviate disease. For similar reasons, sugarbeets are produced on a parcel of land only once in three to four years. However, such rotational benefits may be less pronounced for small grain crops. Nonetheless, if such advantages exist, producers must consider potential changes in net returns and the riskiness of those net returns prior to adopting these strategies.

Even with substantial rotational benefits, an additional enterprise may not increase mean net returns because of additional management, labor, timing, and capital investments. From an economic perspective, expanding enterprise diversity may or may not result in income diversification. That is, it may or may not be a means to the desirable end of reducing the variance of net returns while maintaining an acceptable level of mean returns.

Economists are often asked to assess the economic profitability of introducing specialty crops into established crop rotations. However, the issue of risk associated with such activity is often overlooked. Once measure of the riskiness of income flows is variance. The standard variance formula for a portfolio of n crops indexed by i allocated by proportions λ_i over the farm's acreage and with returns r_i is (see Johnson and Tefertiller 1964 and Newbery and Stiglitz 1981):

$$(1) \qquad Var = \Sigma_i \lambda_i^2 \operatorname{var}(r_i) + 2\sum_{i \neq j} \lambda_i \lambda_j Cov(r_i, r_j)$$

Clearly, even if the covariance terms between crops $Cov(r_i,r_j)$ are negatively correlated, overall variance may increase with the introduction of a high-variance new crop.[2] In addition, overall farm income variance may decline from the introduction of a moderate risk crop that has a low positive correlation with existing crops.

In the mid-1960's, Johnson and Tefertiller (1964) evaluated the effects of production portfolios on risk. Both the theory and empirical findings from this body of work have been invaluable to producers, extension agents, and others. However, this work has historically required several limiting assumptions such as non-skewed distributions, a limited number of enterprises, and limited correlation structures. More recently, numerical estimation and distribution fitting procedures allow for the relaxation of these assumptions.

There is no guarantee, nor useful rule of thumb, that the addition of a crop reduces net income risk. A clear answer is, however, obtainable through empirical investigation of the type presented in this paper.

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[2] For a single crop (λ_1=1.0), the condition for the marginal addition of a new crop to decrease overall farm variance is that $Cov(r_1,r_2) < [var(r_1)-var(r_2)]/2$

A portfolio assessment is difficult for specialty crops because of their short production histories and limited price series. Specialty crop prices are often characterized by thin markets and private negotiations. We simulate net returns using estimates of price and yield distributions obtained from limited secondary data and ancillary information. Our whole-farm approach provides useful distributional results, mean-variance tradeoffs, and safety criterion for assessing the relative merits of various rotations.

We evaluate the economic variability of adding two different types of chickpeas into a wheat/barley/fallow rotation in Northeast (NE) Montana. One type of chickpeas, large kabulis, offer a high risk and high mean value of returns-over-variable-costs (ROVC). The second type, desi or small kabulis (hereafter desi chickpeas), offers a relatively low ROVC in terms of mean and variance.

A thorough investigation of risk must include a time-series element. That is, a host of events influence prices and yields for each of these crops. Any given year's estimates ignore the impact of risk over time. One could use experimental data for such analyses if a lengthy data series were available. However, this is not the case with respect to chickpea production. Therefore, we use simulation techniques that randomly select yield and price outcomes from empirical probability distributions. Simulation results are collected for each random draw. An empirical probability distribution is then generated to produce an estimate of the mean and variance of ROVC.

Our analysis considers net farm revenues on a whole-farm basis for a NE Montana farm that includes both crop and fallow acres. Northeast Montana is an important growing region for spring wheat, durum, and increasingly, various specialty crops. Individual crop yield and price distributions for the crops included in the rotations considered are determined by using available regional, Canadian, and world-wide data. A final distribution for whole-farm net revenues is determined empirically by simulating draws from the individual crop yield and price distributions. Our estimations account for the effects of applicable crop insurance and loan rate programs. We use the distributional analysis package @Risk™ for our analysis.[3]

II. METHODS: MODELING PROCEEDURES

Rotations

The net returns are considered for four rotations over a hypothetical 1,500 acre NE Montana grain farm. All of the rotations complete their cycles in three years, and each rotation splits the farm into three fields of 500 acres each. In each rotation, one field is planted to hard red spring wheat (HRS) on land that was chemically fallowed the previous year. A second field is planted to barley, HRS, or chickpeas on land that produced HRS in the previous year. A third field is chemically fallowed (Table 1).

These rotations were developed to reflect spring wheat, fallow, and other crop acreages in NE Montana. Although this is a geographically large and diverse area, these budgets should provide information on the relative returns and variability of returns for these rotations. Crop yield and price distributions for wheat and barley reflect historical (1980-2004) data for NE Montana. Crop yields are calculated on a per-planted acre basis and were linearly detrended. Wheat and barley prices represent average marketing year prices (Montana Agricultural Statistics). Wheat yield distributions reflect data from NE Montana. Chickpea yield and price data are obtained from producers and Canadian and world market data (Table 2)

During 2003/2004 crop year, just over 50% of NE Montana (non-hay) crop acres were planted to spring wheat or durum. Approximately 50% of the spring wheat acreage was recrop during this period. Fallow acres in 2003 in NE Montana were approximately 30% of tilled acres. A number of alternative crops were produced in the region including barley (7% of non-hay crop acreage), oats (2%), peas and lentils (1%), canola (1%), and flax (0.7%) (Montana Agricultural Statistics).

[3] @Risk™ is a commercial add-on to Microsoft Excel™. Other programs such as Simetar™ can perform similar evaluations.

Crop Budgets

HRS and Barley Budgets

Our rotational analyses require representative budgets that accurately reflect revenues and costs. We revised and updated existing crop budgets for the NE Montana region from an earlier extensive study of producers in this area (Johnson et al. 1998a). These budgets were revised to reflect changes in production technology (e.g., reduced tillage needs because of the use of air seeders).

The Johnson et al. (1998a) budgets were updated for current output prices and yields (Montana Agricultural Statistics, various issues) and fuel, fertilizer, and herbicide costs. This and all subsequent budgets include only operating costs (omitting machinery ownership, labor, management, and land costs). The HRS budgets for production on fallow and recrop are given in Tables 3 and 4, respectively. The barley budget is given in Table 5. Crop insurance expenditures are included in the budgets and result in a yield floor that is 70% of mean wheat and barley yields.

Desi Chickpea Budgets

We used producer interviews, discussions with chickpea researchers, published yields (Montana Agricultural Statistics, various issues) and commercial input to construct budgets for desi chickpeas (Table 6). The budget includes two fungicide treatments for ascochyta blight. Machinery operating costs were based on producer surveys regarding tillage, seeding, herbicide, and harvesting operations. Prices were based on 2004 Canadian chickpea market prices. Crop insurance expenditures provide a yield floor of 70% of mean yields for desi chickpeas.

Large Kabuli Chickpea Budgets

We used producer interviews, discussions with chickpea researchers, published yields (Montana Agricultural Statistics, various issues) and commercial input to construct the large kabuli chickpea budget (Table 7). The budget includes four fungicide treatments for ascochyta blight. Machinery operating costs are based on producer surveys regarding tillage, seeding, herbicide, and harvesting operations. Prices represent Canadian chickpea market prices in 2004. Crop insurance expenditures are not included because the Risk Management Agency requires the planting of ascochyta resistant chickpea varieties which essentially precludescrop insurance coverage for large kabuli chickpeas (Brester and Buschena).

Chemical Fallow

Fallowing costs were updated from those reported by Johnson et al. (1998a). These budgets were updated for current output prices and yields (Montana Agricultural Statistics, various issues) and fuel, fertilizer, and herbicide costs (Table 7).

III. METHODS: YIELD AND PRICE DISTRIBUTIONS

HRS and Barley

Mean NE Montana yields and statewide marketing year average prices from 1980-2004 were used to define distributions for the simulations. The best fitting distribution for detrended yields for each crop was selected using the @RISK™ program's data fitting procedure. After each distribution was selected, a yield for the 2005 crop was estimated based on historical trends. These estimates were used as the mean yields for the simulation. Real prices (2005 base, estimated) were used in similar fashion to define the HRS and barley price distributions. Three yield distributions were defined (HRS on fallow, HRS recrop, and barley following HRS). The best fitting distributions for yield were:

HRS on fallow – Logistic(30.77, 3.25)

HRS on HRS stubble – Logistic (26.72, 3.50)

Feed Barley on HRS stubble – Logistic (44.242, 4.732)

For every sample yield that was less than 70% of the mean, the yield was replaced with 70% of mean yields to reflect the impact of crop insurance purchases. The best fitting distributions for prices were:

HRS – Beta General (1.369, 1.603, 2.586, 4.661)

Barley - Normal (1.9, .497)

For every sample price that was less than the applicable marketing loan rate, the price was replaced with the loan rate.

Desi and Kabuli Chickpeas

Montana chickpea price and yield data have not been consistently reported. However, Canadian chickpea yields are well-established. Therefore, we used Canadian chickpea yield data (1997 – 2004) to define the best fitting distributions for chickpeas, and adjust the mean of this distribution using survey data from Montana producers.

The Canadian data do not distinguish between desi and kabuli chickpea yields. Therefore, a single distribution was estimated, and the means of the distribution was adjusted based upon survey information. The yield distributions for chickpeas used in the simulations were:

Desi Chickpeas - Extreme Value (1682, 204.58)

Kabuli Chickpeas - Extreme Value (900.3, 204.58)

For sample desi chickpea yields that were less than 70% of the expected yield, each observation was replaced with 70% of mean yields to reflect the purchase of crop insurance. However, that procedure was not used in the kabuli simulations because of the lack of crop insurance options (Brester and Buschena 2005).

A consistent set of Canadian chickpea price data were unavailable. Therefore, a price series for chickpea imports by India was used to estimate price distributions. The Indian prices were adjusted for exchange rates, and a single distribution was estimated for desi chickpeas. The kabuli price distribution was then adjusted to reflect differences in mean prices obtained from limited Canadian data and from surveys of Montana chickpea producers. The variance for Kabulis was also increased based upon industry discussions. The price distributions used in the simulations were:

Desi chickpeas – Log Normal (.0107, .0066)

Kabuli chickpeas – Log Normal (.0288, .016)

For samples of desi prices that were less than the marketing loan rate ($.0743/lb.), each observation was replaced by the loan rate.

Correlations

It is likely that crop yield and price distributions are somewhat correlated. For example, high HRS yields should be correlated with high barley yields, and perhaps, chickpea yields. Barley, HRS, and chickpea prices may be positively correlated. In addition, prices and yields for a single crop may be negatively correlated, although the yield/price correlations are expected to be relatively weak for any single crop given that Montana is a relatively small producer of all three crops.

Montana data for wheat and barley (1980-2004 for HRS and barley) were used to estimate the sample price and yield correlations. Data limitations did not allow for the empirical estimated of such correlation with respect to chickpeas. Therefore, these correlations were inferred. We assume a zero price/yield correlation for chickpeas grown in Montana due to the crop's limited production in the state. The resulting correlation matrices for each rotation were defined within @RISK, and the simulation program accounted for this correlation when sampling from the price and yield distributions.

The correlation matrices for each of the four rotations were:

Rotation 1

	HRS on Fallow yield	HRS Price	Recrop Barley Yield	Barley Price
HRS on fallow yield	1.0			
HRS price	-.252	1.0		
Barley on stubble yield	.949	-.210	1.0	
Barley Price	-.181	.762	-.294	1.0

Rotation 2

	HRS on Fallow yield	HRS Price	Recrop Desi Yield	Desi Price
HRS on fallow yield	1.0			
HRS price	-.252	1.0		

Desi on stubble yield	0.90	0.0	1.0	
Desi Price	0.0	0.0	0.0	1.0

Rotation 3

	HRS on Fallow yield	HRS Price	Recrop Kabuli Yield	Kabuli Price
HRS on fallow yield	1.0			
HRS price	-.252	1.0		
Kabuli on stubble yield	0.8	0.0	1.0	
Kabuli Price	0.0	0.0	0.0	1.0

Rotation 4

	HRS on Fallow yield	HRS Price	Recrop HRS Yield
HRS on fallow yield	1.0		
HRS price	-.252	1.0	
HRS on stubble yield	0.912	-.212	1.0

IV. RESULTS AND DISCUSSION

Yields and prices were drawn for each crop within each rotation 1,000 times from the distributions and correlations listed above. Each crop's gross revenues were calculated on a per acre basis after adjusting for any effects of crop insurance on yields and loan rates for wheat, barley, and desi chickpeas. Operating expenses were then subtracted from revenues to obtain ROVC. The per acre average returns for each rotation were then calculated. Essentially, this procedure produces 1,000 annual ROVC observations for the sample farm for each rotation. These observations are then used to calculate the mean and variance of ROVC.

Each rotation's mean, standard deviation, and coefficient of variation are reported in Table 9. Per acre net returns for each rotational distribution's lower quartile, lower decile, and the likelihood that the rotation provides a net return above operating costs of at least $30/acre are also reported in Table 9. The $30 level was selected because is represents approximate cash land rental rates in NE Montana.

Rotation 1: HRS – Feed Barley – Fallow

Figure 1 illustrates the probability distribution for average net per acre returns for Rotation 1. This figure provides an illustration of and summary statistics for the probability density function (pdf) for the rotation. Table 9 provides summary information for the net returns distributions for each of the four rotations.

The best fitting distribution for the average per acre net returns for Rotation 1 was a Weibull (2.50, 31.09), shift -5.09 distribution with a mean of $22.50 and a standard deviation of $11.80 per acre.

Rotation 2: HRS – Desi Chickpeas – Fallow

Figure 2 illustrates the probability distribution for average net per acre returns for Rotation 2.

The best fitting distribution for the average per acre net returns for Rotation 2 was a LogNormal (58.02, 14.2), shift -28.4 distribution with a mean of $29.6 and a standard deviation of $14.2 per acre.

Rotation 3: HRS – Kabuli Chickpeas – Fallow

Figure 3 illustrates the probability distribution for average net per acre returns for Rotation 3.

The best fitting distribution for the average per acre net returns for Rotation 3 was a Pearson5 (19.0, 1786.6), shift -68.6 distribution with a mean of $30.80 and a standard deviation of $24.10 per acre.

Rotation 4: HRS – HRS (recrop) – Fallow

Figure 4 illustrates the probability distribution for average net per acre returns for Rotation 4.

The best fitting distribution for the average per acre net returns for Rotation 4 was a Gamma (28.9, 2.7), shift -51.5 distribution with a mean of $27.40 and a standard deviation of $14.70 per acre.

Summary of Simulation Results

Rotation 1 had the smallest standard deviation of the four. However, it did not have the lowest coefficient of variation. It also had a low likelihood of receiving a return over $30 per acre. Rotation 4 (recrop spring wheat) is a more common rotation in NE Montana. It has a higher mean and larger probability of producing ROVC greater than $30/acre. Rotation 2 has a slighter higher mean, lower coefficient of variation, and a similar probability of a ROVC greater than $30/acre relative to Rotation 4. The inclusion of desi chickpeas could be thought of as a proxy for a variety of specialty crops produced in NE Montana. Thus, this cropping system approximates many of the actual production systems being employed in NE Montana. Finally, Rotation 4 provides the largest mean ROVC and the largest probability of producing more than $30/acre. However, it also has the largest coefficient of variation indicating that this is the riskiest of the four rotations. The higher risk of including kabuli chickpeas in a rotation results from limited crop insurance alternatives and the lack of a loan rate .

V. EXTENSIONS

Distributional Adjustments

A number of alternatives in the distributional relationships could be considered in the future if data were available. First, increased chickpea data availability could be used to refine relevant price and yield correlations. Second, additional rotations could be explored as additional yield, price and budget information for other pulse crops becomes available. Finally, rank correlation approaches that ensure marginal distributions could be incorporated into the simulations (Brester, Marsh, and Atwood 2004).

Assessing Agronomic Benefits

Chickpeas are thought to provide agronomic benefits to wheat-fallow rotations because they may intervene in disease cycles and improve nutrient availability. These benefits are not accounted for in the analysis summarized in Table 9, and they give rise to difficulties in communication between agronomists or other plant scientists and economists. The simulation method developed here allows for a useful evaluation of the potential size that these agronomic benefits that must occur if Rotation 3 is to compete with a more traditional rotation (Rotation 4).

To assess the potential effects, we estimate the HRS yield increases that would have to occur for the rotational benefits of kabuli chickpeas to offset their additional risk. This simulation was conducted by estimating the wheat yield increase necessary for the likelihood of the lowest decile ROVC of Rotation 4 ($9.30 per acre) to have a 10% chance of occurrence under the mean-shifted distribution for Rotation 3. This required a yield increase in HRS of 5.75 bushels per acre. This entire increase would have to be produced because of the inclusion of chickpeas in Rotation 4. This represents an 18.7% increase in mean yields. Given that wheat yields have increase approximately 0.5% annual for past several decades, an 18.7% rotational increase seems relatively large.

Rotations with Reduced Chickpea Acreage

We considered an additional rotation introduces smaller large Kabuli chickpea acreages into Rotation 3. The motivation for this alternative stems from equation (1) and footnote 2. That is, the addition of a riskier crop can reduce overall variation of a production portfolio if the share of the additional crop is relatively small. This result can occur even if the ROVC of the two crops are positively correlated. Thus, Rotation 3a adjusts Rotation 3 by splitting crop acreage in Year 2 between kabuli chickpeas (100 acres) and wheat recrop (400 acres).

The correlation matrices used for simulating these rotations were similar to those for Rotation 3. The yield correlations of large Kabuli chickpeas to HRS on fallow and HRS recrop were assigned a value of 0.85.

Figure 5 illustrates the probability distribution for average net per acre returns for Rotation 3a. In addition, the results for Rotation 3a are reported in the last row of Table 9. The best fitting distribution for the average per acre net returns for Rotation 3a was a Gamma (8.8, 5.3), shift -17.6 distribution with a mean of $28.50 and a standard deviation of $15.50 per acre. This rotation produces a slightly larger mean ROVC than Rotation 4, and a similar coefficient of variation. Nonetheless, Rotation 2 provides a larger mean and a smaller coefficient of variation. However, Rotation 3a does offer an insight into the type of crop rotation expansion followed by many producers. That is, producers often dedicate relative small shares of cropland to specialty crops.

VI. CONCLUSIONS

We simulated crop rotations using HRS, Barely, and chickpea yield and price distributions to assess ROVC mean/variance tradeoffs of adding chickpeas to wheat-fallow rotation sin NE Montana. We included crop insurance and loan rate impacts, and considered potential rotational benefits of chickpeas. We evaluated four rotations, two traditional rotations with wheat, barley (or wheat recrop) and fallow, and two non-traditional rotations that incorporated chickpeas, a specialty crop.

The whole-farm simulations allow comparisons of the rotations and proved risk/return tradeoffs for producers. We find that the inclusion of desi chickpeas can improve mean ROVC and somewhat lower risk. In essence, the inclusion of desi chickpeas is a proxy for other types of specialty crops that are produced in NE Montana. We also find that the agronomic benefits to wheat production required for the rotation including high risk chickpeas would have to by quite large (almost a 19% yield increase) for this rotation to dominate the most favorable traditional wheat-fallow rotation.

This paper outlines a method for evaluating rotational differences based on a whole-farm analysis of simulated returns. This method incorporates crop budgets, yield distributions, price distributions, and distributional correlations into a simulation analysis for farm returns.

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Table 1. Crop Rotations Used in the Simulations.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Rotation 1	HRS	Feed Barley	Chem Fallow	HRS	Feed Barley	Chem Fallow
Rotation 2	HRS	Desi Chickpeas	Chem Fallow	HRS	Desi Chickpeas	Chem Fallow
Rotation 3	HRS	Lg. Kabuli Chickpeas	Chem Fallow	HRS	Lg. Kabuli Chickpeas	Chem Fallow
Rotation 4	HRS	HRS	Chem Fallow	HRS	HRS	Chem Fallow

Table 2. Primary Yield and Price Data. Blank cells indicate missing data.

Year	Canadian Chickpea Yield/Lbs. per Acre	Real Indian Chickpea Price/$U.S./Lb.	NE Montana HRS Yield After Fallow/Bu. Per Acre	NE Montana HRS Yield Recrop/Bu. Per Acre	NE Montana HRS MYA Wheat Price	NE Montana Recrop BarleyYield/Bu. Per Acre	NE Montana Real MYA Barley Price
1980			11.5	6.39	7.88	9.1	3.59
1981			19.5	13.57	6.34	25.6	2.84
1982			26.8	24.83	5.62	37.2	2.37
1983			19.9	13.01	5.88	23.9	2.66
1984			14.8	9.37	5.47	19.6	2.57
1985			7.8	3.82	5.21	7.8	2.11
1986			22.9	23.40	3.67	24.8	1.63
1987			25.0	25.05	3.79	31.6	1.80
1988			5.5	1.29	5.38	6.4	2.69
1989			16.2	14.01	4.61	22.9	2.03
1990			10.3	6.22	3.41	12.8	2.03
1991		.139	26.6	17.26	3.82	36.2	2.34
1992		.118	32.9	24.24	4.09	38.7	2.16
1993		.138	32.1	23.83	4.10	34.2	2.03
1994		.137	30.7	25.11	3.88	31.7	2.05
1995		.139	25.8	21.54	4.97	26.0	2.98
1996		.144	21.8	21.78	4.49	22.4	2.60
1997	1232.1	.158	22.2	22.16	3.74	28.5	2.19

1998	1170.4	.141	26.5	19.67	3.24	31.7	1.46
1999	1179.5	.153	27.2	25.23	3.03	28.6	1.56
2000	1170.4	.161	28.2	22.38	3.02	23.5	1.60
2001	835.8	.155	25.8	23.82	2.98	21.5	1.83
2002	633.2	.167	22.9	19.14	3.91	23.0	2.10
2003	961.9	.170	24.7	21.37	3.56	21.1	1.97
2004	860.9	.205	30.0	27.24	3.32	26.2	1.90

Table 3. Representative Enterprise Budget for Spring Wheat, Minimum Till System after Fallow.

	Unit	$/unit	Quantity	Total
Expected Gross Income:				
	bushels	$3.60	28	$101.00[1]
Expected Production Costs:				
Seed and Treatment		$5.80	1.08	$6.26
Fertilizer, 20-20-10	ton	$230.00	0.05	$11.50
2,4-D LV6	gal.	$19.00	0.2	$3.75
Bronate (Ally)	oz.	$22.00	0.1	$2.20
Fargo	lb.	$0.90	1.25	$1.13[2]
Crop Insurance				$6.00
Machinery Operating Costs				$15.81
Interest Costs on Operating				$1.63[3]
Total Operating Costs				$48.28
Returns Above Operating				$52.52

[1] Price is the Montana Marketing Year Average, 2004.

[2] Apply Fargo on 1/2 of acres at a rate of 2.5 pounds per acre.

[3] Six months at a 7% annual rate.

Table 4. Representative Enterprise Budget for Spring Wheat, Minimum Till System after HRS.

	Unit	$/unit	Quantity	Total
Expected Gross Income:				
	bushels	$3.60	23	$83.00[1]
Expected Production Costs:				
Seed and Treatment		$5.80	1.08	$6.26
Fertilizer, 20-20-10	ton	$230.00	0.06	$13.80
2,4-D LV6	gal.	$19.00	0.2	$3.75
Bronate (Ally)	oz.	$22.00	0.1	$2.20
Fargo	lb.	$0.90	1.25	$1.13[2]
Crop Insurance				$6.00
Machinery Operating Costs				$15.81
Interest Costs on Operating				$1.70[3]
Total Operating Costs				$50.14
Returns Above Operating				$32.66

[1] Price is the Montana Marketing Year Average, 2004.

[2] Apply Fargo on 1/2 of acres at a rate of 2.5 pounds per acre.

[3] Six months at a 7% annual rate.

Table 5. Representative Enterprise Budget for Feed Barley, Minimum Till System after Wheat.

	Unit	$/unit	Quantity	Total
Expected Gross Income:				
	bushels	$1.60	27	$43.00[1]
Expected Production Costs:				
Seed and Treatment		$3.50	0.95	$3.33
Fertilizer, 20-20-10	ton	$230.00	0.03	$6.90
2,4-D LV6	gal.	$19.00	0.2	$3.75
Bronate (Ally)	oz.	$22.00	0.1	$2.20
Fargo	lb.	$0.90	1.25	$1.13[2]
Crop Insurance				$3 .00
Machinery Operating Costs				$15.81
Interest Costs on Operating				$1.26[3]
Total Operating Costs				$37.37
Returns Above Operating				$5.83

[1] Price is the Montana Marketing Year Average, 2004.

[2] Apply Fargo on 1/2 of acres at a rate of 2.5 pounds per acre.

[3] Six months at a 7% annual rate.

Table 6. Representative Enterprise Budget for Small Kabuli and Desi Chickpeas, Minimum Till System after Spring Wheat.

			High Input Scenario	
	Unit	**$/unit**	**Quantity**	**Total**
Expected Gross Income:				
	lbs.	$0.08	2000	$160.00[1]
Expected Production Costs:				
Seed and Treatment	lb.	$0.39	90	$35.10
Fertilizer, 20-20-10	ton	$230.00	0.04	$9.20
Assure II post-emerge	oz.	$1.14	7	$7.98
Surfactant		$0.20	1	$0.20
Ascochyta Treatments	(Requires Scouting and early application)			
Quadris	oz.	$2.34	6.0	$14.04
Quadris	oz.	$2.34	6.0	$14.04
Crop Insurance				$8.00
Machinery Operating Costs				$17.19
Interest Costs on Operating				$3.70[2]
Total Operating Costs				$109.45
Returns Above Operating				$50.55

[1] Price is the Montana Marketing Year Average, 2004.

[2] Six months at a 7% annual rate.

Table 7. Representative Enterprise Budget for Large Kabuli Chickpeas, Minimum Till System after Spring Wheat.

			High Input Scenario	
	Unit	**$/unit**	**Quantity**	**Total**
Expected Gross Income:				
	lbs.	$0.18	1000	$180.00
Expected Production Costs:				
Seed and Treatment	lb.	$0.48	120	$57.60
Fertilizer, 20-20-10	ton	$230.00	0.04	$9.20
Assure II post-emerge	oz.	$1.14	7	$7.98
Surfactant		$0.20	1	$0.20
Ascochyta Treatments	(Requires Scouting and early application)			
Bravo Weatherstick	pint	$5.71	1.4	$7.99
Bravo Weatherstick	pint	$5.71	1.4	$7.99
Quadris	oz.	$2.34	6	$14.04
Quadris	oz.	$2.34	6	$14.04
Crop Insurance				$8.00
Machinery Operating Costs				$18.13
Interest Costs on Operating				$5.08[1]
Total Operating Costs				$150.25
Returns Above Operating				$29.75

[1] Six months at a 7% annual rate.

Table 8. Representative Chemical Fallow Budget.

	Per application					
	unit	**units**	**price/unit**	**total/application**	**# applications**	**Total**
Roundup	oz	$20	0.12	$2	5	$12
Application Costs				2	5	$10
Total						$22

Table 9: Comparative Summary Statistics for Per Acre Returns Distributions

Rotation	Mean ($/acre)	St. Dev.	Coefficient Of Variation	Lower Quartile ($/acre)	Lower Decile ($/acre)	Probability That ROVC > $30/acre
Rotation 1: HRS-Feed Barley - Fallow	22.5	11.8	0.52	13.8	7.5	35.9%
Rotation 2: HRS-Desi Chickpeas-Fallow	29.6	14.2	0.48	19.5	12.9	41.0%
Rotation 3: HRS-Kabuli Chickpeas-Fallow	30.8	24.1	0.78	13.7	3.7	45.2%
Rotation 4: HRS-HRS Recrop –Fallow	27.4	14.7	0.54	17.1	9.3	40.7%
Rotation 3a: HRS-Kabuli Chickpeas/HRS Recrop – Fallow	28.5	15.5	0.54	17.3	10.0	41.7%

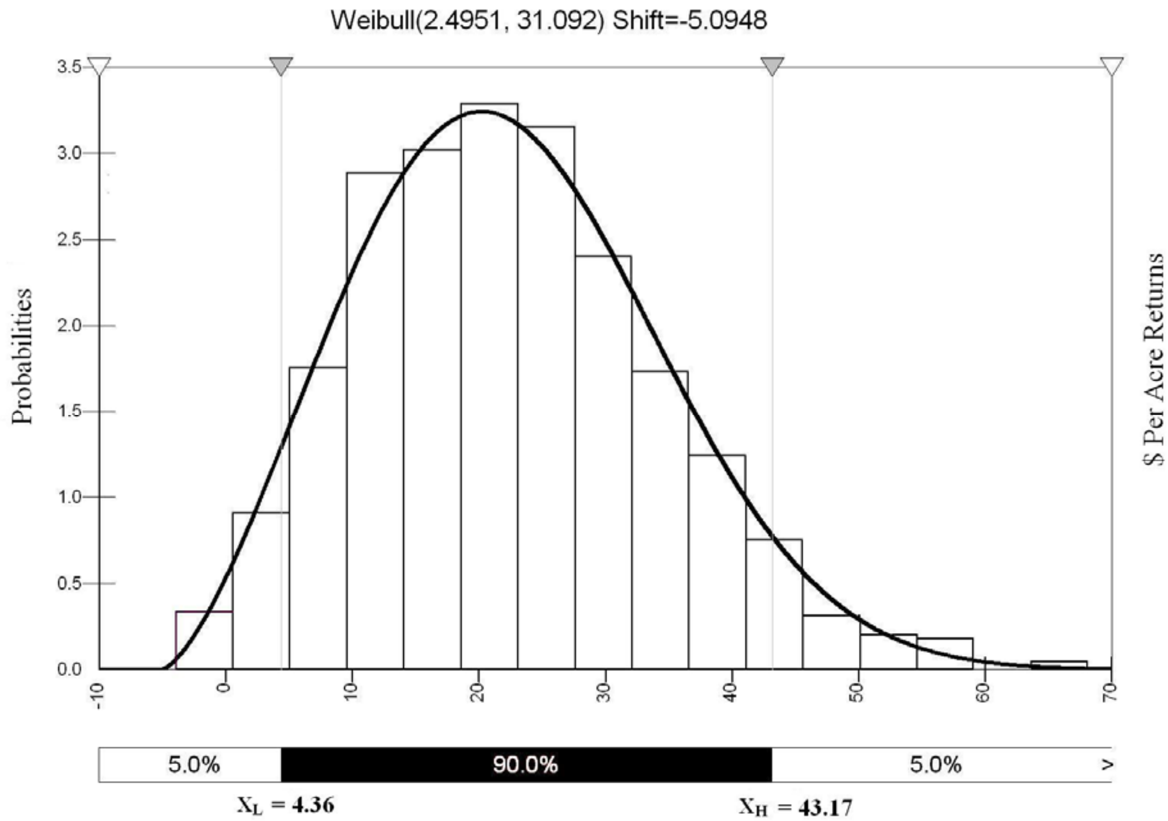

Figure 1. Rotation 1: Net Returns Per Acre Distribution.[4]

[4] X_L is the per acre return for which the probability of $X < X_L$ is 5%.
X_H is the per acre return for which the probability of $X < X_H$ 95%.

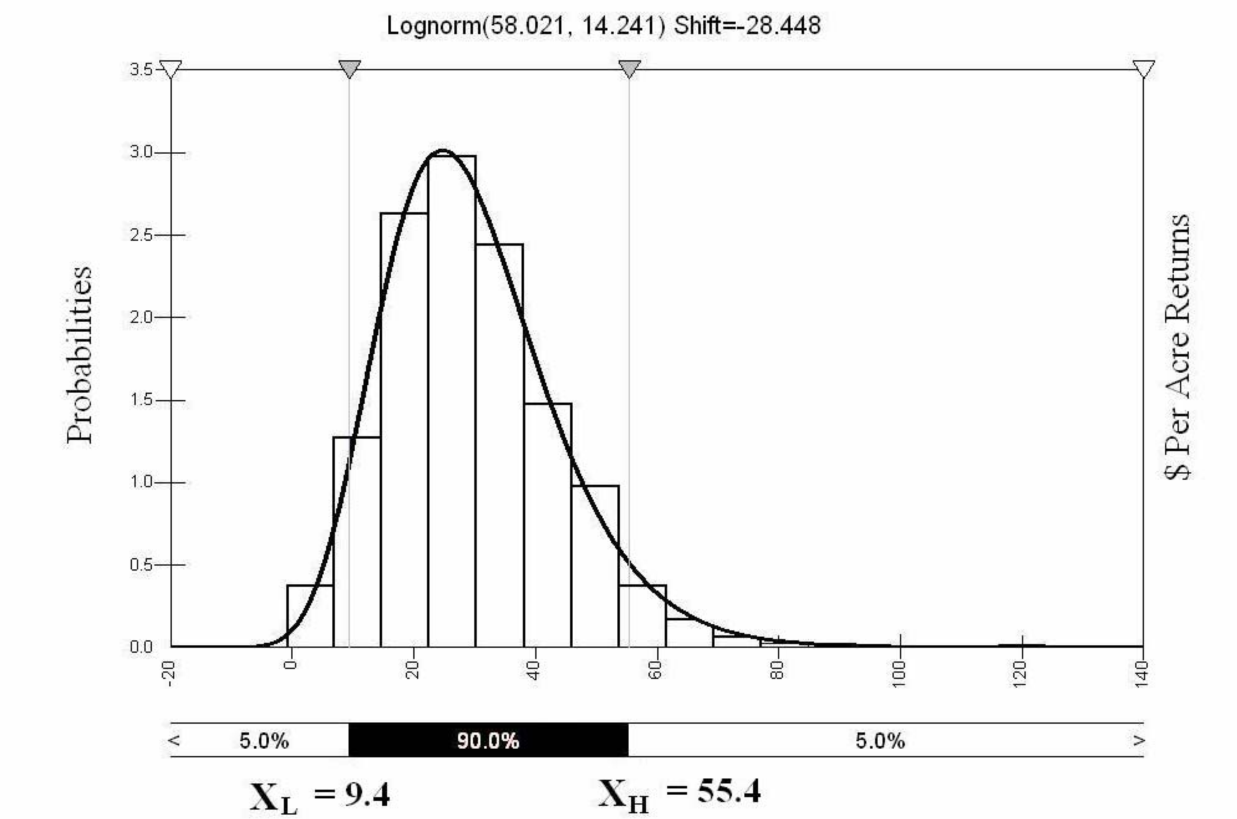

Figure 2. Rotation 2: Net Returns Per Acre Distribution.[5]

[5] X_L is the per acre return for which the probability of $X < X_L$ is 5%.
X_H is the per acre return for which the probability of $X < X_H$ 95%.

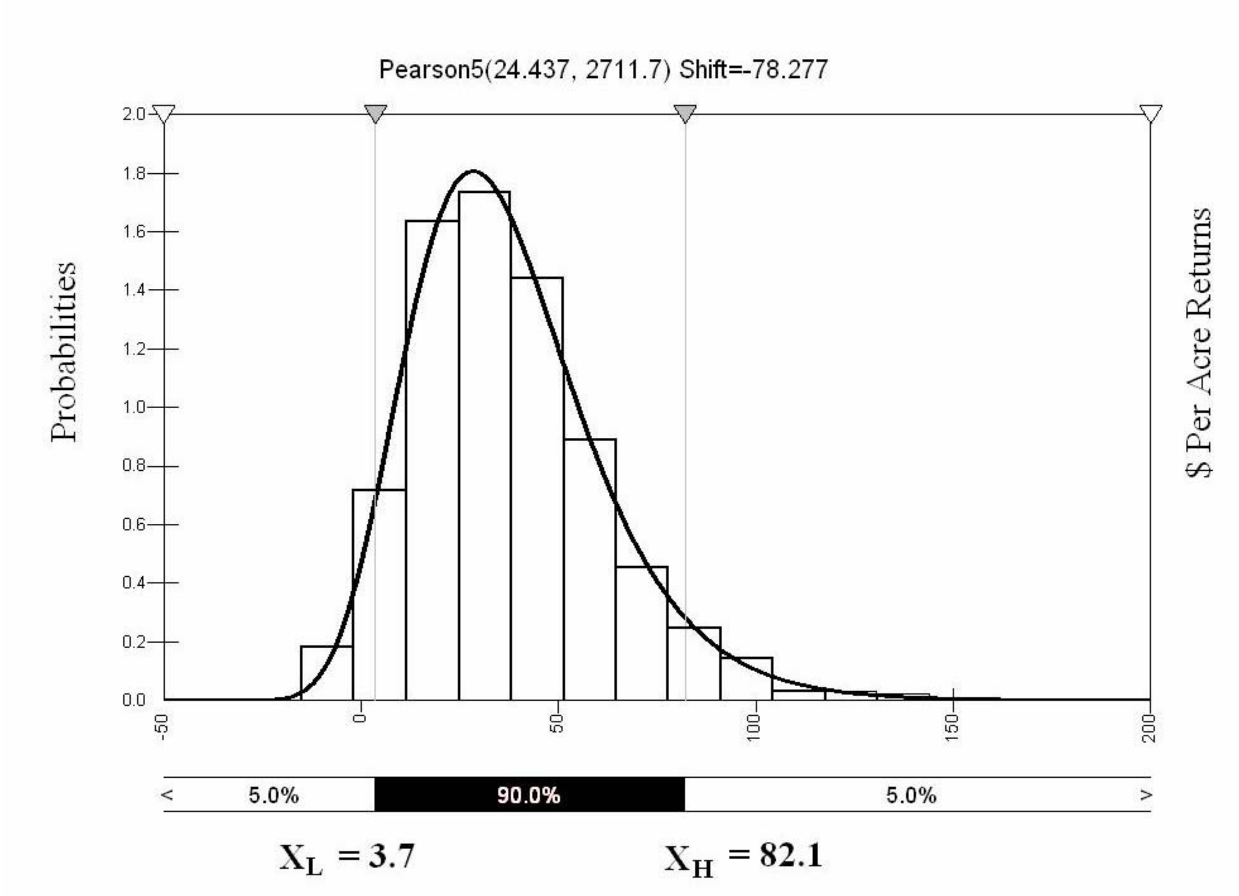

Figure 3. Rotation 3: Net Returns Per Acre Distribution.[6]

[6] X_L is the per acre return for which the probability of $X < X_L$ is 5%.
X_H is the per acre return for which the probability of $X < X_H$ 95%.

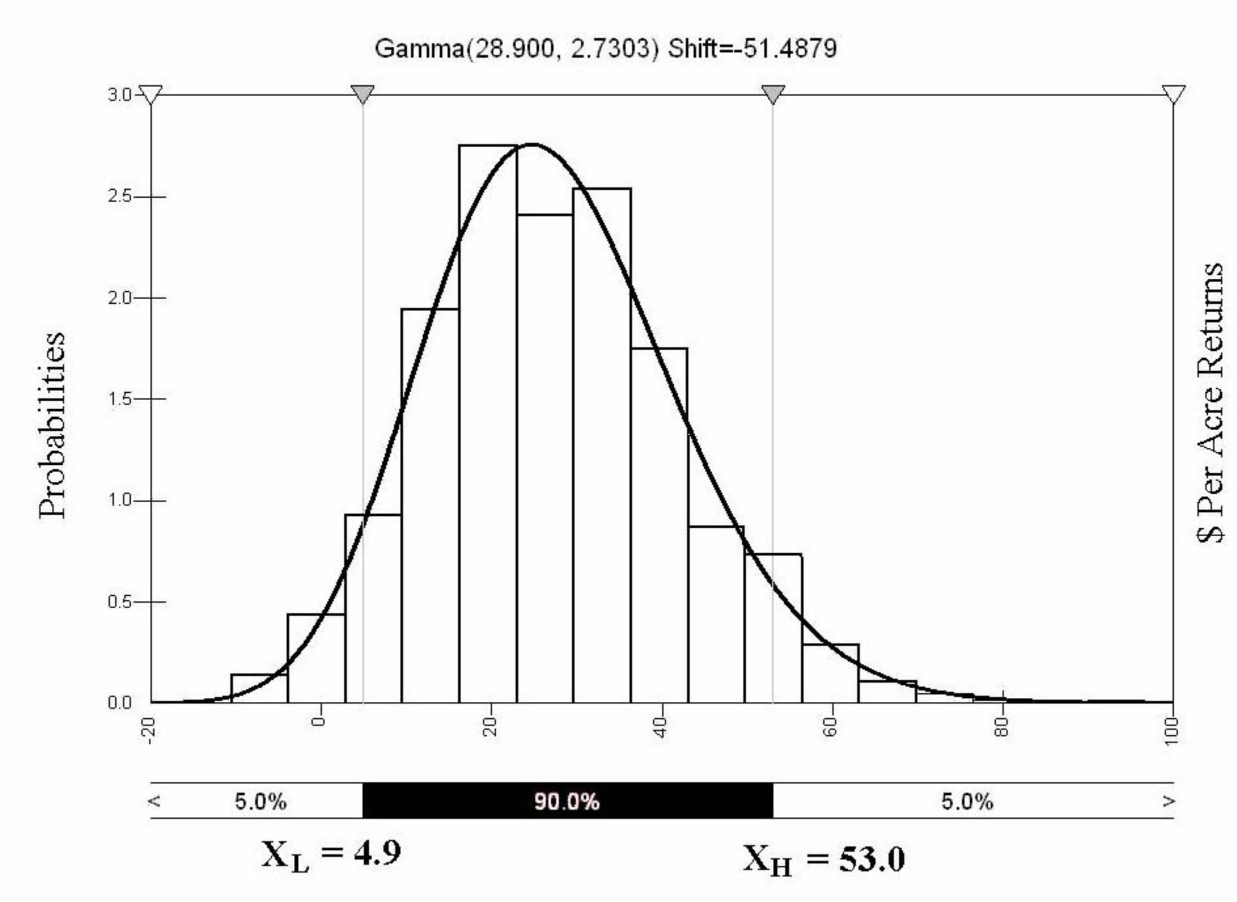

Figure 4. Rotation 4: Net Returns Per Acre Distribution.[7]

[7] X_L is the per acre return for which the probability of $X < X_L$ is 5%.
X_H is the per acre return for which the probability of $X < X_H$ 95%.

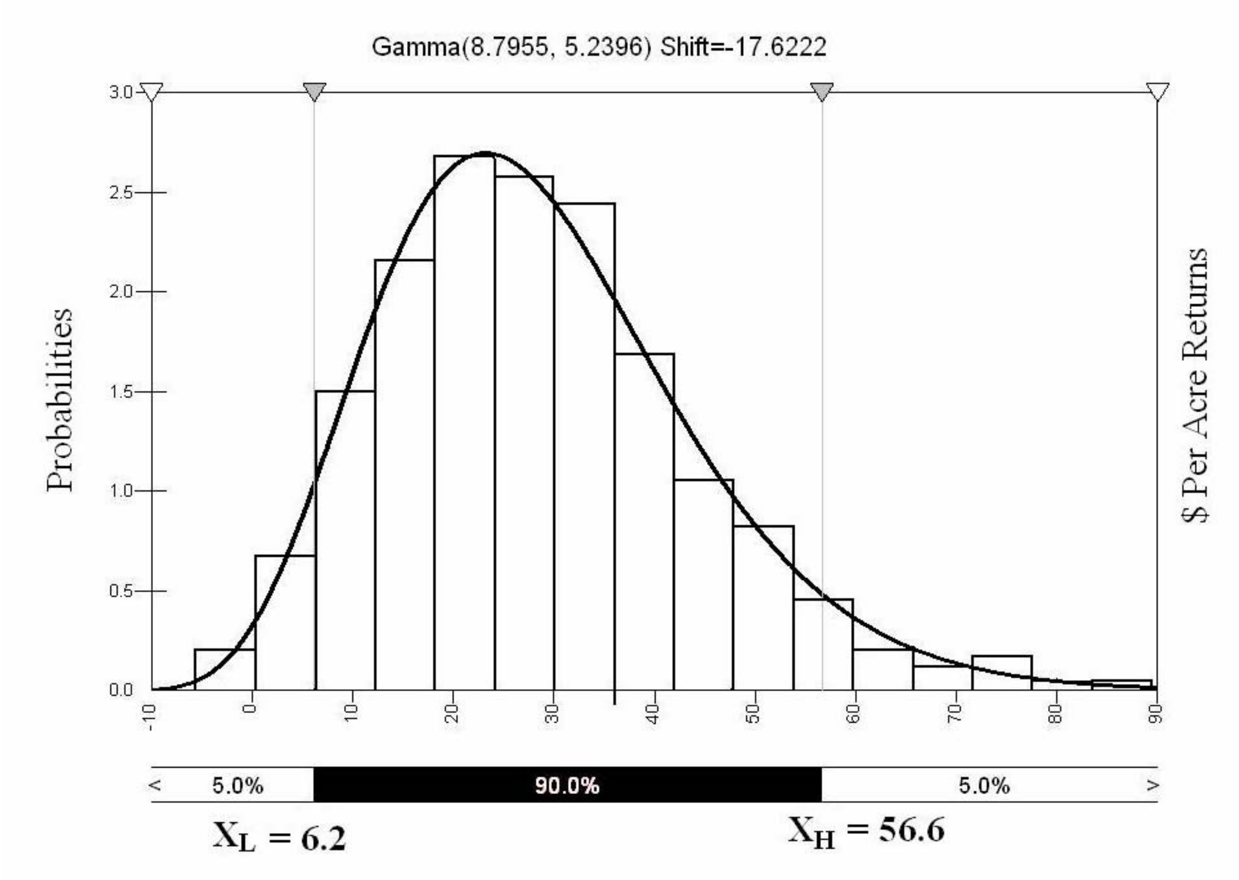

Figure 5. Rotation 3a: Net Returns Per Acre Distribution.[8]

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[8] X_L is the per acre return for which the probability of X < X_L is 5%.
X_H is the per acre return for which the probability of X < X_H is 95%.