

Replacing Summer Fallow with a Summer Grazed Legume Crop in Rotation with Wheat or Wheat-Sunflower-Millet

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Abstract

Profitability and risk, 1988-2001, are examined for lamb-grazed field pea as a fallow replacement with a wheat-fallow rotation, or extended wheat-sunflower-millet wheat-sunflower-millet-pea rotations. Switching from a conventional wheat-fallow to an extended rotation with grazed-peas increases the rate of return to farmland (2.3% to 7.3%), and reduces downside risk with losses in only two versus seven of fourteen years).



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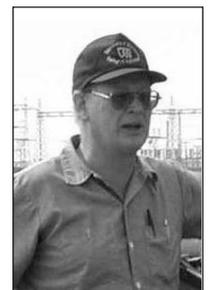
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Introduction

Wheat growers in the West Central High Plains states of the United States (Western South Dakota, Western Nebraska, Kansas, Eastern Wyoming, and Colorado) are struggling to maintain long-term profitability, challenging them to rethink traditional crop rotation and fallow management practices. A simple two-year rotation, winter wheat followed by a year of idle fallow, traditionally has been used to replenish soil moisture. Unfortunately, summer fallow has proved to be inefficient for soil moisture storage due to evaporation and deep soil losses. With conventional tillage, usually less than 25 percent of the precipitation received during the fallow period is available for a subsequent wheat crop; even no-till is inefficient (40%) for water conservation (Peterson, et al., 1996). In addition, fallow has created a host of adverse effects, including reduced organic matter and soil fertility, possible leaching of root zone nutrients, greater susceptibility to erosion, air pollution, and surface and ground water pollution. Finally, fallow is costly, requiring two acres of land to grow one acre of wheat.

Improved dryland practices have been studied and recommended to improve profitability and sustainability. These include longer rotations with different crops to break critical weed, disease and insect cycles, as well as moisture conserving fallow practices (Anderson et al., 1999). An analysis of dryland winter wheat farms in Kansas showed that diversified operations are relatively more profitable than those specializing in wheat only (Langemeier et al., 1999). Integrating dryland crops and livestock is another promising approach for achieving sustained profitability (Krall and Schuman, 1996). A survey of dryland producers in Wyoming showed widespread interest in adopting reduced input practices that are profitable (Krall et al., 1991).

In addition to narrow profit margins, wheat farming has also been subject to extreme business risk (income variability), as a result of fluctuating yields and prices. Yields are dependent on uncontrolled forces of nature, including variable growing season precipitation. For example: from 1988 to 2001, winter wheat yields at the Archer Research and Extension Center in southeast Wyoming¹ wheat yields averaged thirty-one bushels

per acre, ranging from a high of sixty bushels per acre (1995) to a low of nineteen bushels per acre (2001). Wheat yields are directly dependent on variable growing season precipitation (ranging from eight to sixteen inches at the same site), which is received on top of a very limited amount of moisture made available from the previous 14-month fallow period. While year-to-year precipitation variability cannot be eliminated, its adverse impact on income variability can be minimized with better management practices. For example, a review of previous dryland cropping studies indicates that more intensive crop rotations and better tillage practices not only generates more profit, but in many cases reduces the amount of business risk (Dhuyvetter, et al., 1996).

Objective

This article examines profitability and multi-year business risk that is associated with growing and grazing an annual legume, Austrian winter pea (*Pisum sativum* subsp. *arvense*), as an alternative to conventional fallow, either in rotation with wheat as a single crop, or in rotation with wheat and several other dryland crops.

Data and Approach

Annual rates of return to farmland are estimated for four alternative cropping systems over a 14-year period (1988-2001), including: (1) wheat following conventional fallow, (2) wheat following Austrian winter pea, (3) wheat following sunflower, millet, and conventional fallow, and (4) wheat following sunflower, millet, and Austrian winter pea. Rates of return for each system are derived from historic experimental yields, state/regional product prices, and estimated costs of production (Haag, 2001). Besides profitability, cropping systems are also compared with respect to income variability and downside risk. Finally, rotations are ranked by order of preference for risk-averse decision makers. Downside risk is measured by the frequency (number of years in fourteen, 1988-2001), that the rate of return to farmland falls below a designated target rate, e.g., zero percent. A target rate in this article represents a minimum required rate to avoid financial stress.

Crop Rotation Studies

Yield data for the economic analysis were collected from two separate studies at the Archer Research and Extension Center in southeast Wyoming. The first is an ongoing four-year rotation study (wheat-sunflower-millet-fallow), conducted over the past fourteen years (1988-2001) on experimental strips ranging from two to four acres in size.

A second study, conducted on experimental plots at Archer (1995 to 2001), was designed to evaluate the impact of growing wheat after Austrian winter pea fallow (as opposed to conventional fallow), with respect to yield, protein content, and other selected factors. In addition, the performance of lambs grazing Austrian winter pea was evaluated over a portion of the study period (1996-1999). Austrian winter pea was planted in the fall, and then grazed by lambs the following summer for an average length of twenty days.² The best practice was to conclude grazing by the first week of July, after producing a reasonable quantity of forage. This was followed by termination of peas (with tillage) to assure an adequate store of soil moisture for planting wheat in the fall. Over the years of the study, lambs weighing sixty to ninety pounds were stocked at an average rate of fourteen lambs per acre. During this time,

lambs generated an average gain of 0.50 pounds per day, or 140 pounds per acre, with per acre gains ranging from 100 to over 200 pounds.

Crop Yields

Table 1 summarizes fourteen years (1988-2001) of crop yield data for both the four-year rotation study and the Austrian winter pea study. For comparison, local Laramie County wheat yields are also shown. Yield data for wheat and sunflowers in the four-year rotation study were unavailable in 1996 (hail), and are estimated with selected yield/precipitation equations.³ Similarly, wheat yields for the Austrian winter pea study were not available for the years preceding 1995 (1988-94) and 1996 (hail), and are estimated with linear regression. For the six year period of observed yields in Table 1 (1995, 1997-2001), wheat yields from the four year rotation study (Ws-m-f) were found to be closely related or highly correlated (0.923 and 0.886) with wheat yields in the Austrian Winter Pea study (Wf and WP).⁴ For the years 1988-94 and 1996 (hail), wheat yields for these two rotations (Wf and WP) were estimated with linear regression, using wheat yield data (Ws-m-f) from four-year rotation study, (1995, 1997-2001) as the independent variable (x), and respective wheat yields for wheat-fallow (Wf) and wheat-graze pea (WP), for the same years (1995, 1997-2001),

Table 1: Annual yields for dryland crops in southeast Wyoming, 1988-2001.

Years	Four-year rotation study ¹			Wheat-pea study ²		County yield ³
	Wheat (Ws-m-f)	Sunflowers (S)	Millet (M)	Wheat (Wf)	Wheat (WP)	Wheat (W _{Co.})
	bu/acre	cwt/acre	cwt/acre	bu/acre	bu/acre	bu/acre
1988	38	14	12	39	34	27
1989	25	9	10	26	25	20
1990	34	12	14	35	32	30
1991	30	16.5	15	31	29	30
1992	21	8	10	23	23	26
1993	32	11.5	25	33	30	29
1994	26	6	11	27	26	22
1995	60	8.5	12	57	47	37
1996	34	13	10	35	31	27
1997	22	17	18	29	33	32
1998	27	13.5	17.5	19	22	30
1999	42	16.5	22	52	42	31
2000	23	7	14.5	25	22	19
2001	<u>19</u>	<u>9.5</u>	<u>16</u>	<u>19</u>	<u>17</u>	<u>20</u>
Avg.	31	11.6	14.8	32	29	27
Std. dev. ⁴	11	3.7	4.6	11	9	5
CV ⁵	0.355	0.319	0.311	0.344	0.31	0.185

¹ Unpublished yield data for wheat (Ws-m-f) in a four-year rotation with sunflowers (S), millet (M) and fallow (f), at the University of Wyoming, Archer R & E Center in southeast Wyoming. Yield data for wheat and sunflowers were not available in 1996 (hail). Using precipitation data at Archer, Wyoming, 1996 wheat and sunflower yields were estimated with yield/precipitation response equations developed at Akron, Colorado (Neilsen, 1995).

² Wheat yields for wheat-fallow (Wf) and wheat-graze pea (WP), are from rotation studies conducted at the Archer R & E Center, 1995-2001. For the years 1988-94 and 1996, wheat yields for these two rotations were estimated with linear regression, using wheat yield data (Ws-m-f) from the 4-year rotation study, (1995, 1997-2001) as the independent variable; and respective wheat yields for wheat-fallow (Wf) and wheat-graze pea (WP), for the same years (1995, 1997-2001) as the dependent variables.

³ Non-irrigated wheat yields for Laramie County in southeast Wyoming (Wyo. Agric. Stat.).

⁴ Standard deviation is a statistical measure of dispersion around an average, larger values indicate greater amounts of business risk (Barry, et. Al., p.663. A standard deviation for a column of 14 numbers within a Microsoft Excel worksheet can be easily derived with the following formula;=STDEV(a1:a14).

⁵ CV refers to the coefficient of variation, which measures relative variability, and is a more appropriate measure of business risk when comparing two variables having different units, i.e., wheat=bu/acre versus Millet=cwt/acre> It is simply calculated by dividing the average by the standard deviation, e.g. 31/11 = 0.355 (Barry, et. al., p.64 8).

as dependent variables ($R^2 = 0.85$ and 0.73 respectively). For the six year period of observed yields in Table 1 (1995, 1997-2001), wheat yields from the four year rotation study (Ws-m-f) were found to be highly correlated (0.923 and 0.886) with wheat yields in the Austrian Winter Pea study (Wf and WP).⁴

For the years 1988-94 and 1996 (hail), wheat yields for these two rotations (Wf and WP) were estimated with linear regression, using wheat yield data (Ws-m-f) from four-year rotation study, (1995, 1997-2001) as the independent variable (x); and respective wheat yields for wheat-fallow (Wf) and wheat-graze pea (WP), for the same years (1995, 1997-2001), as dependent variables ($R^2 = 0.85$ and 0.73 respectively).³

Over the fourteen year period, average wheat yield from the four-year rotation, Ws-m-f (31 bushels) is slightly lower than conventional wheat-fallow, Wf (32 bushels). Wheat yield following grazed Austrian winter pea (WP) is also lower (29 bushels).⁵ Although average wheat yields in the four-year rotation study (31 bu/acre), and after Austrian winter pea (29 bu/ac) are numerically lower than wheat yield after conventional fallow (32 bu/acre), they are not statistically

different (1995, 1997-2001): $p = 0.05$. Observing lower wheat yields after Austrian winter pea is consistent with previous wheat-legume studies at Akron, Colorado which also showed yield reductions for wheat after a legume (6 bushel/acre) compared to wheat after conventional fallow (Vigil and Nielsen, 1998).

Lower average yield (29 vs. 32 bu/ac) from wheat following Austrian winter pea at Archer, Wyoming was compensated by higher quality wheat. Over the years of the study, average protein percentage for wheat following grazed-pea (14.1%) was higher than wheat after conventional fallow (12.4%). This difference was statistically significant: $p = 0.05$.

Local county wheat yields averaged twenty-seven bushels per acre, and are less variable ($CV = 0.185$), likely because county yields are based on averages of larger sized tracts than small tract site specific yields at Archer. Annual yield variability for crops grown at Archer are similar, with CVs ranging from 0.310 to 0.355. The magnitude of crop yields at Archer, Wyoming (Table 1), corresponds closely to the range of yields reported at Akron, Colorado (Vigil, et al., 1997).⁶

Table 2: Annual prices for crops and lambs, 1988-2001.¹

Years	Products				
	Wheat ² (Wf)	Wheat ³ (Wp)	Sunflowers ⁴ (S)	Millet ⁵ (M)	Lambs ⁶ (L)
	—\$/bu—		—\$/cwt—		
1988	4.37	4.45	12.96	7.87	77.84
1989	4.5	4.51	11.47	6.64	85.34
1990	2.8	2.86	11.64	4.97	63.36
1991	3.03	3.04	8.71	3.64	61.43
1992	2.95	3.11	10	4.74	71.53
1993	3.19	3.70	13.33	8.08	63.54
1994	3.54	3.69	11.08	8.77	77.64
1995	4.55	4.81	12.01	6.03	94.3
1996	4.41	4.42	11.52	5.86	101.24
1997	3.44	3.67	11.33	4.45	89.54
1998	2.3	2.85	10.59	4.23	94.26
1999	2.44	3.15	7.31	4	87.37
2000	2.34	2.62	6.48	9.53	89.22
2001	<u>2.7</u>	<u>2.85</u>	<u>8.08</u>	<u>4.15</u>	<u>75</u>
Avg.	3.33	3.55	10.46	5.93	80.83
Std. dev. ⁷	0.83	0.74	2.08	1.95	12.73
CV ⁸	0.249	0.208	0.2	0.329	0.157

Table 2 shows annual prices for lambs and dryland crops. Wheat yields in the four-year rotation (Ws-m-f) were not strongly correlated with either sunflowers (0.130) or millet (0.025), both of which rely more on mid to late summer precipitation.⁴ Correlation between millet and sunflowers is also low (0.467). Low yield correlation between crops is desirable for reducing whole-farm income variability with product diversification, since a poor yield from one crop is not likely to occur when poor yields occur with other crops. Wheat yields at Archer are highly correlated with local county wheat yields

¹ Product prices are converted to a 2001 real dollar basis, using the Producer Price Index.
² Price for wheat produced after conventional fallow (Wf) is Wyoming summer price at harvest (Wyo. Agric. Stat.).
³ Price for wheat produced after grazed peas (WP) is Wyoming summer price at harvest, plus a protein premium, representing the difference between Kansas City ordinary versus Kansas City 13% protein wheat (Wheat Yearbook, ERS, USDA), in response to higher average protein from wheat grown after winter peas (14.1%), compared to wheat after conventional fallow (12.4%).
⁴ Annual sunflower prices are not reported in Wyoming; and are based on an average of oilseed prices reported for Kansas, Nebraska and Colorado (Crop values, NASS, USDA).
⁵ Annual millet prices, are not reported in Wyoming; and are based on September harvest price for western Nebraska (Burgener, et al., 2001).
⁶ Wyoming lamb prices reported in July (Wyo. Agric. Stat.)

(0.661 or higher), reflecting the influence of similar precipitation events.

Product Prices

Table 2 shows product prices for computing annual revenues, 1988-2001. Because wheat produced after Austrian winter pea, WP, has a higher protein percentage (14.1%) than wheat grown after conventional fallow, Wf (12.4%), it is priced higher with a protein premium.⁷ Lamb prices from 1988-2001 were more stable (CV=0.157) than crop prices. Millet prices were the most variable of all (CV=0.329).

Rotation net returns

Annual costs and returns, 1988-2001, were generated for a total of four rotations: (1) wheat after conventional fallow (f) every other year, W-f-W-f; (2) wheat after grazed pea fallow (P) and then conventional fallow every other year, W-P-W-f; (3) wheat-sunflower-millet followed by conventional fallow, W-S-M-f; and (4) wheat-sunflower-millet followed by grazed pea fallow, W-S-M-P. Table 3 shows average (1988-2001) gross return, total cost, and net return for each rotation, using average yields and prices from 1988 to 2001.

Costs between rotations (shown in Table 3) were affected by the frequency and type of fallow practice. The cost of conventional

Table 3: Average Net return (1988-2001) of four crop rotations: (1) wheat with conventional fallow (f) every other year, W-f-W-f; (2) wheat with graze peas (P) and conventional fallow (f) every other year, W-P-W-f; (3) wheat-sunflower-millet with conventional fallow, W-S-M-f; and (4) wheat-sunflower-millet with graze peas, W-S-M-P.

(1) W-f-W-f	Wheat	Fallow	Wheat	Fallow	Average
Returns					
• yield (per acre)	31 bu	-	31 bu	-	-
• price (per unit)	<u>\$3.33</u>	-	<u>\$3.33</u>	-	-
RETURN(\$/ac) ¹	103.23	0	103.23	0	51.62
Costs (\$/ac) ²	<u>49.49</u>	<u>42.16</u>	<u>49.49</u>	<u>42.16</u>	45.83
Net return (\$/ac)	53.74	-42.16	53.74	-42.16	5.79
Rate of return ³	-	-	-	-	2.30%
(2) W-P-W-f					
Returns					
• yield (per acre)	31 bu	35 lbs	29 bu	-	-
• price (per unit)	<u>\$3.33</u>	<u>\$0.81</u>	<u>\$3.55</u>	-	-
RETURN(\$/ac) ¹	103.23	28.35	102.95	0	58.63
Costs (\$/ac) ²	<u>49.49</u>	<u>55.65</u>	<u>48.72</u>	<u>42.16</u>	49.01
Net return (\$/ac)	53.74	-27.3	54.23	-42.16	9.62
Rate of return ³	-	-	-	-	3.80%
(3) W-S-M-f					
Returns					
• yield (per acre)	31 bu	11.6 cwt	14.8 cwt	-	-
• price (per unit)	<u>\$3.33</u>	<u>\$10.46</u>	<u>\$5.93</u>	-	-
RETURN (\$/ac) ¹	103.23	121.34	87.76	0	78.08
Costs (\$/ac) ²	<u>45.68</u>	<u>96.35</u>	<u>63.68</u>	<u>42.16</u>	61.97
Net return (\$/ac)	57.55	24.99	24.08	-42.16	16.11
Rate of return ³	-	-	-	-	6.40%
(4) W-S-M-P					
Returns					
• yield (per acre)	29 bu.	11.6 cwt	14.8 cwt	35 lbs	-
• price (per unit)	<u>3.55</u>	<u>\$10.46</u>	<u>\$5.93</u>	<u>\$0.81</u>	-
Total (\$/ac) ¹	102.95	121.34	87.76	28.35	85.09
Costs (\$/ac) ²	<u>44.91</u>	<u>96.35</u>	<u>63.68</u>	<u>55.65</u>	65.15
Net return (\$/ac)	58.04	24.99	24.08	-27.3	19.94
Rate of return ³	-	-	-	-	7.90%

¹ Crop returns are the product of average 1988-2001 yields (Table 1) and 1988-2001 average prices (Table 2). AVERAGE Pea grazing income (\$28.35/acre) is based on a wheat grower receiving 35% of the value of a 100 lb. lamb gain (35 lb.) times an average lamb price (\$0.81/lb).

² Detailed cost budgets were developed by Haag (2001), and updated with current input prices. Costs includes all items, except a charge for land. Machinery costs are based on custom rates (Hewlett, et al.).

³ Rate of return (to farmland) is net return to land (\$/ac) divided by an estimated land value of \$250/acre.

fallow (f), \$42.16 per acre, includes a post-harvest herbicide application followed by four tillage operations. Pea fallow (P) is more expensive (\$55.65 per acre), as a result of costs for planting peas, herbicide, and one tillage (to terminate peas in July). The cost of pea fallow is partially defrayed by modest income from grazing lambs (\$28.35 per acre). In addition to lamb prices, the net return from wheat produced after Austrian winter pea fallow is influenced by yields and prices that are different from those associated with wheat grown after conventional fallow. For example, considering rotation #2 (W-P-W-f), the total average net return from wheat after pea fallow (\$9.62 per acre) was slightly higher than wheat after conventional fallow (\$5.79 per acre), in spite of lower wheat yield (29 versus 31 bushels per acre). However, the adverse affect of lower wheat yield was partially offset by a protein

Table 4: Annual and 14-year average (1988-2001) rates of return to land, and selected measures of variability and risk, given alternative crop rotations.

Items:	Crop rotations ¹			
	-1 W-f-W-f	-2 W-P-W-f	-3 W-S-M-f	-4 W-S-M-P
—years ² —	%			
1988	13.3	13	17.6	17.7
1989	4	5.4	2.8	4.7
1990	-0.2	0.1	4.6	5.2
1991	-0.7	-0.4	3.3	3.9
1992	-5.2	-3.7	-5.9	-3.9
1993	1.3	2.8	19.2	21
1994	-0.2	1.3	0.2	1.9
1995	29.1	28.2	17.4	15.3
1996	10.5	11.2	9.8	10.8
1997	0.5	4.2	9.2	15
1998	-9.5	-5.6	2.5	4.9
1999	4.2	6.8	5	9.6
2000	-7.1	-5.3	-1.4	0.8
2001	<u>-8.1</u>	<u>-7</u>	<u>-5.3</u>	<u>-4.3</u>
Avg. (%)	2.3	3.6	5.6	7.3
Std. dev. (%) ³	10.1	9.3	8.1	7.8
CV ⁴	4.423	2.554	1.436	1.068
Years (in 14) < 0.0 %	7/14	5/14	3/14	2/14

premium and higher wheat price (\$3.55 versus \$3.33 per bushel).

Results

Table 3 summarizes average gross returns, costs, and net returns for each of the four rotations, using average (1988-2001) yields and prices. Even though rotations with pea fallow and/or additional crops are more costly, higher profits are realized as a result of even larger gross returns. Adopting pea fallow (#2) in place of conventional fallow (#1), provides a modest \$3.83 per acre net return increase (\$5.79 to \$16.11 per acre). Switching to a wheat-sunflower-millet rotation (#3) from wheat alone (#1) gives an even larger gain in net return (\$10.32 per acre), from \$5.79 to \$16.11 per acre. Growing wheat with sunflowers and millet, after grazed pea fallow (#4) yields the highest overall net return (\$19.94 per acre).

Profitability and Risk

Table 4 shows annual 1988-2001 rates of return to farmland valued at \$250/acre and is calculated as the dollar net return to farmland, divided by \$250 per acre land value. Table 4 also shows selected measures of income variability (standard deviation, and CV, coefficient of variation) from each of the four rotations, 1988-2001.¹¹ In addition, downside risk is featured in terms of target losses, i.e., the frequency (years in fourteen that losses are incurred) or that annual rates of return are below a target of zero percent (Held, 1990). The traditional wheat fallow rotation, W-f-W-f (#1), is by far the poorest by all measures: (1) least profitable (2.3% average rate of return), (2) highest income variability (CV = 4.423), and (3) greatest downside risk (below zero percent target in seven of fourteen years). Compared to using conventional fallow every other year, W-f-W-f (#1), substituting grazed pea fallow every four

¹ W-f-W-f = Wheat-fallow-Wheat-fallow; W-P-W-f = Wheat-Pea(graze)-Wheat-fallow; W-S-M-f = Wheat-Sunflower-Millet-fallow; W-S-M-P = Wheat-Sunflower-Millet- Pea(graze).

² Calculation of rates of return, are illustrated for each rotation in Table 3.

³ Standard deviation is a statistical measure of dispersion around an average, largervalues indicate greater amounts of business risk (Barry, rt. Al., p.663) A standard deviation for a column of 14 numbers within a Microsoft Excel worksheet can be easily derived with the following formula;=STDEV(a1:a14).

⁴ CVrefers to the coefficient of variation, which measures relative variability, and is a more appropriate measure of business risk when comparing two items having different averages, and is simply computed by dividing an average by a corresponding standard deviatio, i.e., 2.3 1/10.1 = 4.423 (Barry, rt. al., p.648).

years, W-P-W-f (#2), increases profitability (2.3% to 3.6%), and decreases income variability and downside risk (below the zero percent target in only five versus seven of fourteen years). An even greater jump in profitability comes from switching to a four-year rotation of wheat-sunflower-millet, either with conventional fallow, W-S-M-f, #3 (from 2.3% to 5.6%), or with grazed pea fallow, W-S-M-P, #4 (from 2.3% to 7.3%). Switching to either of these rotations, provides an even greater reduction in income variability and downside risk. Rates of return are below zero percent in only two or three years (versus seven) of the 14-year period.

Stochastic Dominance

Risk-neutral decision makers base their choices on highest average profit, and accordingly, would show preference for these rotations in descending order of profitability, from highest to lowest average rate of return: (1) W-S-M-P =7.3%, (2) W-S-M-f =5.6%, (3) W-P-W-f =3.6%, and (4) W-f-W-f =2.3%. Because lower standard deviations, in this case, are associated with rotations having higher rates of return, it would appear that

this same order of preference would also apply to those who are risk-averse.

To further examine the preference ranking of risk-averse decision makers, cumulative probability distributions (CPDs) were developed to show the likelihood that the rate of return for a given rotation will drop below any one of a series of target rates (Table 5).¹² Compared to the traditional W-f-W-f (#1) rotation, all of the alternatives (#2, #3, and #4) appear to be better for those who are risk-averse, since there is a much smaller chance of falling below any of the lower tier, disaster-level targets (-8% to 0%), as well as medium tier targets (0% to +16%). However, the traditional W-f-W-f rotation (#1) may be better for those who are not risk averse, and enjoy satisfaction from an occasional but exceptionally large rate of return. The traditional W-f-W-f rotation (#1) renders a smaller chance of falling below any of the upper tier targets (above 20%).

Table 5 compares CPDs (cumulative probabilities) for the conventional wheat-fallow rotation, W-f-W-f (#1), against each of the other rotations: W-P-W-f (#2), W-S-M-f (#3), and W-S-

Table 5: Probabilities that percentage rates of return will fall below specified target rates of return, given alternative crop rotations.

Target rates of return ¹	Crop rotations			
	(1) W-f-W-f	(2) W-P-W-f	(3) W-S-M-f	(4) W-S-M-P
	—————Cumulative probabilities—————			
-10%	0	0	0	0
-8%	0.14	0	0	0
-6%	0.21	0.07	0	0
-4%	0.29	0.21	0.14	0.07
-2%	0.29	0.29	0.14	0.14
0%	0.5	0.36	0.21	0.14
2%	0.64	0.5	0.29	0.29
4%	0.71	0.57	0.5	0.36
6%	0.79	0.71	0.64	0.57
8%	0.79	0.79	0.64	0.57
10%	0.79	0.79	0.79	0.64
12%	0.86	0.86	0.79	0.71
14%	0.93	0.93	0.79	0.71
16%	0.93	0.93	0.79	0.86
18%	0.93	0.93	0.93	0.93
20%	0.93	0.93	1	0.93
22%	0.93	0.93	1	1
24%	0.93	0.93	1	1
26%	0.93	0.93	1	1
28%	0.93	0.93	1	1

¹ Cumulative frequencies (percentages) for the 0% target, shown previously on the bottom of Table 4, i.e., 0.50 corresponds to missing a 0% target in 7 out of 14 years, $7/14 = 0.50$.

M-P (#4)). In all cases, the CPDs for a target rate of 18 percent are very close (CPD=0.79 - 0.93) at a target rate of 18 percent., indicating very similar probabilities of realizing a rate of return to farm land below 18 percent, given all four rotations. This precludes using first-degree stochastic dominance, and limits the ranking of these rotations to those who are risk-averse.¹³ Subjecting these rotations to second-degree stochastic dominance analysis (Goh, et. al), confirmed that in this particular case, risk-averse decision makers would indeed rank these four rotations in the same order of preference that was noted for those who are risk neutral, i.e., the most preferred for risk-averse decision-makers are W-S-M-P (#4) over W-S-M-f (#3) over W-P-W-f (#2) , over the least preferred W-f-W-f (#1).

Discussion

A wheat-fallow rotation has been a conventional standard for years, in part, because it is relatively easy to manage and operate. Over time, however, growing wheat as a single crop has created serious weed and pest problems, many of which have become increasingly difficult and expensive, if not impossible, to control. In addition, summer fallow has created very serious soil management problems, which will further erode future profit margins. This article has examined profitability and business risk associated with several dryland wheat-fallow rotations for the West Central High Plains states of the United States (Western South Dakota, Nebraska, Kansas; Eastern Wyoming, and Colorado).

A conventional wheat-fallow rotation was confirmed to be the poorest with respect to both profitability and risk. In many situations, switching to a higher profit alternative comes at the cost of incurring more business risk. In this case, however, there was no trade off. Moving from conventional fallow to any of the other rotations generated more profit, along with less income variability and downside risk. In this study, growing wheat with other crops (sunflowers and millet) had a more profound impact on improving profitability and risk than modifying the fallow practice with Austrian winter pea. However, implementing both practices together appears to be by far the best choice.

The added profitability from adopting grazed pea fallow appeared to be quite modest in the context of this analysis.

Indeed, if deteriorating soil quality and land productivity were not such serious problems, growing and grazing peas as a substitute for conventional fallow may not be viewed by some as worth the extra time and effort. However, the case for growing and grazing an annual legume (such as Austrian winter pea) becomes a lot more compelling when considering other long term benefits, all of which could eventually contribute to even better sustained profitability: (1) nitrogen is supplied for future crops through the break down of plant material and animal waste, (2) water holding capacity, nutrient levels, and microorganisms are increased with more soil organic matter, and (3) soil cover is better, reducing erosion.

Although lower yields were noted with wheat following grazed Austrian winter pea, soil quality improvements over time may reduce or possibly eliminate these yield reductions. Added benefits of pea-grazed fallow were also limited by a rather high cost of establishing Austrian winter pea (\$20 per acre), and a relatively short time-span (three weeks) for grazing lambs. Future research may alleviate some of these limitations. For example, efforts are underway to develop annual regenerative legumes that can readily survive the harsh environment of the Central High Plains and are suitable for grazing by either cattle or sheep.

While switching to a pea-graze fallow system in concert with an extended rotation appears to be a promising way to improve both profitability and income stability, it is recognized that the reality of extra time and effort associated with growing more crops and managing livestock is no small matter. The uncertainty and learning curve associated with a new practice can be in itself, a profound source of risk which is not easily measured or considered in this analysis. These and other factors may very well dampen their appeal for many producers. Unfortunately for some, there may not be a choice. Business survival in dryland farming may ultimately depend on implementing these and other types of new practices.

Endnotes

- ¹ Wheat yields are from unpublished data for a dryland crop rotation study (wheat-sunflowers-millet-fallow), 1988-2001, at the University of Wyoming, Archer Research and Extension Center in southeast Wyoming. Growing season precipitation is that received after planting wheat in September, through June of the following year.
- ² Early spring planting is possible, but fall planting has several advantages including more time to fix nitrogen and develop beneficial soil organisms associated with legumes, as well as to create the desired bio-mass for grazing earlier in the summer.
- ³ Wheat and sunflower yields were estimated with precipitation data at Archer, Wyoming, 1996, using yield/precipitation response equations for wheat and sunflowers developed at Akron, Colorado (Neilson, 1995).
- ⁴ Correlation is "a statistical concept describing the degree of association or interdependence between two variables," (Barry et. al.,p,650), such as crop yield. Correlations close to 1.0 indicate very strong associations, or a nearly perfect tendency for crop yields to move together in the same direction. Yield correlations close to 0.0 indicate that yields of two crops are virtually independent of each other. For example, a yield correlation of 0.61 between COUNTY and ARCHER wheat yields would indicate a strong tendency for COUNTY wheat yields to be higher than average; when ARCHER wheat yields are higher than average, or conversely COUNTY wheat yields would tend to be lower than average, when ARCHER wheat yields are lower than average.
- ⁵ Although average wheat yields in the four-year rotation study (31 bu/acre), and after Austrian winter pea (29 bu/ac) are numerically lower than wheat yield after conventional fallow (32 bu/acre), they are not statistically different (1995, 1997-2001), $p = 0.05$. Observing lower wheat yields after Austrian winter pea is consistent with previous wheat-legume studies at Akron, Colorado, which also showed yield reductions for wheat after a legume (6 bushel/acre).
- ⁶ Dryland yield ranges reported for the Central Great Plains Research Station at Akron, Colorado: wheat (25 to 60 bu/acre), sunflowers (7.5 to 16.0 cwt/acre), and millet (10.0 to 25.0 cwt/acre).
- ⁷ Protein premiums are based on the difference between Kansas City ordinary protein wheat versus 13 percent protein Kansas City winter wheat (Wheat Yearbook, ERS, USDA). Protein premiums between 1988 and 2001, averaged \$0.23/bushel and ranged from a low of \$.01/bushel (1991) to a high of \$.71/bushel (1999).
- ⁸ Rotation #2 (W-P-W-f) limits grazed pea fallow to only 25 percent of farm acreage as opposed to 50 percent (W-P-W-P), since peas grown more frequently can generate serious blight disease problems.
- ¹⁰ Lamb grazing income is different each year, in response to summer lamb prices, and is based on a livestock share of gain approach (35% wheat grower and 65% lamb owner), which allocates revenue proportionate to the percentage of total grazing costs contributed by each party (Langemeier, 1997). Over the 3-week grazing period, the wheat grower is credited with approximately 35 percent of grazing costs (forage, water and fencing); with the lamb owner supplying the other 65 percent (interest on lamb investment, death loss, veterinary expenses, and hauling costs). Per acre lamb gains in the Austrian winter pea study averaged 140 lbs/acre, ranging from 100 to over 200 lbs/acre. Although grazing yields appear to be related to precipitation, limited data prevented an estimation of a functional relationship for this analysis, and 100 lbs/acre is used as a very conservative estimate of gain for each of the 14 years. In 2001, lamb grazing income was \$26.25 per acre, based on a wheat grower receiving a 35% share of a 100 lb per acre lamb gain (valued at \$0.75 per lb).
- ¹¹ Percentage rates of return (annual net return to land/farmland value) as shown in Table 6, 1988-2001, are computed with annual yields (Table 1), and annual prices (Table 2) using the format illustrated in Table 3. Annual costs are expressed in real 2001 real dollars, conforming to annual product prices (also expressed in 2001 real dollars). Annual costs change

from year to year, only to the extent that harvest costs are higher in years of higher yields.

- ¹² As opposed to focusing on the frequency of falling below a single target rate of return (i.e., zero %), the cumulative probabilities in Table 5 provides the same information for a series of multiple targets, ranging from -10% to +28%. Target rates of return are minimum required rates which must be achieved to avoid serious financial stress (Held, 1990).
- ¹³ Stochastic dominance is a common method for evaluating alternative choices with respect to a decision maker's attitude toward risk, and has been used and reviewed in earlier articles in the Journal, including Williams et al. (1988), Johnson et al. (1989), Lyman and Peterson (1991), Brown and Kulshreshtha, (1991) and Held et al. (1993). Second degree stochastic dominance as a risk analysis technique, must be employed when two CPDs under consideration cross, and is restricted to only those decision-makers who are risk-averse. As described by Boehlje and Eidman, an alternative rotation (A) will dominate (be preferred to) traditional rotation (T) with second degree stochastic dominance, "if the area under the cumulative distribution function of A never exceeds and somewhere is less than the area under the cumulative distribution function of T" (p. 467).

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