RISK-RETURN ANALYSIS OF INCORPORATING ANNUAL LEGUMES AND LAMB GRAZING WITH DRYLAND CROP ROTATIONS [a/]

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ABSTRACT

Profitability and risk, 1988-2001, are examined for lamb-grazed field pea as a fallow alternative with wheat, or an extended wheat-sunflower-millet rotation. Switching from conventional wheat-fallow to an extended rotation with grazed-peas increases profitability (2.3% to 7.3%), and reduces risk (below 0% target in only 2 versus 7 of 14 years).

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Risk-Return Analysis of Incorporating Annual Legumes and Lamb Grazing with Dryland Crop Rotations

Wheat growers in the West Central Great Plains of the United States are struggling to maintain long-term profitability, challenging them to rethink traditional crop rotation and fallow management practices. A simple two-year rotation, wheat followed by a year of fallow, has been traditionally 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% of the precipitation received during the fallow period is available for a subsequent wheat crop; and 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 root zone leaching of 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.

To improve profitability and sustainability, improved dryland practices have been studied and recommended. These include longer rotations with different crops to break critical weed, disease and pest cycles, as well as moisture conserving fallow practices. (Anderson et al., 1999). Integrating dryland crops and livestock is another promising approach for achieving sustained profitability (Krall and Schuman, 1996).

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. Figure 1 illustrates the variability of wheat yields and growing season precipitation at the Archer Research and Extension Center in southeast Wyoming.[1] From 1988 to 2001, wheat yields averaged 31 bushels per acre, ranging from a high of 60 bushels (1995) to a low of 19 bushels (2001). Wheat yields are highly correlated (R = 0.67) and very dependent on growing season precipitation (ranging from 8 to 16 inches), which is on top of a very limited amount of moisture made available from the previous 14-month fallow period. While year-to-year precipitation variability can not be eliminated, its adverse effect 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 generate more profit, but in many cases will reduce the amount of business risk (Dhuyvetter, et al., 1996).

Objective

This paper examines profitability and multi-year business risk associated with growing and grazing an annual legume, Austrian winter pea (*Pisum sativus* 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 followed by conventional fallow, (2) wheat followed by Austrian winter pea, (3) wheat followed by sunflower, millet and conventional fallow, and (4) wheat followed by 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.

Crop rotation studies Yield data for the economic analysis, were collected from two separate studies at the Archer Research and Extension Center. The first is an ongoing four-year rotation study (wheat-sunflower-millet-fallow), conducted over the past 14 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 generally planted in the fall, and then grazed by lambs the following summer for an average length of 20 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 60 to 90 pounds were stocked at an average rate of 14 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 14 years (1988-2001) of crop yield data for both the four-year rotation study and the Austrian winter pea study. For comparison, local county-wide 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. [4]

Over the 14-year period, average wheat yield from the four-year rotation, $W_{s\text{-}m\text{-}f}$ (31 bushels) is slightly lower than conventional wheat-fallow, W_f (32 bushels). Wheat yield following grazed Austrian winter pea (W_P) is also lower (29 bushels).[5] Local county wheat yields averaged 27 bushels per acre, and as expected, are less variable (CV = 0.185) than 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 shows yield correlation between dryland crops. Wheat yields in the four-year rotation ($W_{s\text{-}m\text{-}f}$), are not strongly correlated with either sunflowers (0.130) or millet (0.025), both of which rely more on mid to late summer precipitation. 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. Wheat yields at Archer are highly correlated with local county wheat yields (0.661 or higher), reflecting the influence of similar precipitation events.

Product Prices Table 3 shows product prices for computing annual revenues, 1988-2001. Because wheat produced after Austrian winter pea, W_P, has a higher protein percentage (14.1%) than wheat grown after conventional fallow, W_f (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). Table 4 shows that with the possible exception of wheat and sunflowers, prices between other products are not highly correlated, providing additional opportunity to reduce farm income variability with product diversification.

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.[8] Table 5 shows annual gross return, total cost and net return for each rotation, using yields and prices for the most recent year, 2001.[9]

Costs between rotations were affected by the frequency and type of fallow practice. The cost of conventional 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, grazing lambs and one tillage (to terminate peas in July). The cost of pea fallow is partially defrayed by modest income from grazing lambs ($26.25 per acre in 2001), resulting in a smaller negative margin than conventional fallow (–$29.40 versus. –$42.16 per acre in 2001). The net margin from pea-grazed fallow varied over time, ranging from –$34.15 per acre in 1991 (lower lamb prices) to –$20.21 per acre in 1996 (higher lamb prices).[10]

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 return from wheat after pea fallow ($48.45per acre) was slightly lower in 2001 than wheat after conventional fallow ($51.30 per acre), largely the result of a lower wheat yield (17 versus 19 bushels per acre). However, the adverse affect of lower wheat yield in 2001 was partially offset by a protein premium and higher wheat price ($2.85 versus $2.70 per bushel).

Results

Figure 2 summarizes average gross returns, total costs and net returns for each of the four rotations, using average (versus 2001) yields and prices, 1988-2001. Even though rotations with pea fallow and/or additional crops are more costly, higher profits are realized as a result of even larger revenues. Adopting pea fallow (#2) in place of conventional fallow (#1), provides a modest $4 net return increase ($4 to $8 per acre). Switching to a wheat-sunflower-millet rotation (#3) from wheat alone (#1) gives an even larger gain in net return ($10 per acre), from $4 to $14 per acre. Growing wheat with sunflowers and millet, after grazed pea fallow (#4) yields the highest overall net return ($18 per acre).

Profitability and Risk Table 6 shows profitability (annual rate of return), and selected measures of income variability from each of the four rotations, 1988-2001.[11] In addition, downside risk is featured in terms the frequency (years in 14) that annual rates of return are below a target of zero percent. 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 7 of 14 years). Compared to using conventional fallow every other year, W-f-W-f (#1), substituting grazed pea fallow every four 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 5 versus 7 of 14 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 the zero percent target in only 2 or 3 years (versus 7) 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 7).[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 gain satisfaction from an occasional but exceptionally large rate of return. It renders less of a chance of falling below any of the upper tier targets (above 20%).

Graphical pair-wise comparisons of CPDs are shown for the conventional wheat-fallow rotation, W-f-W-f, #1, against each of the other rotations: W-P-W-f, #2 (Figure 3), W-S-M-f, #3 (Figure 4), and W-S-M-P, #4 (Figure 5). In all cases, the CPDs cross at a target rate of 18%. This 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 is 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 with purchased inputs. In addition, summer fallow has created very serious soil management problems, all of which promise to further erode future profit margins.

A conventional wheat-fallow rotation was confirmed to be the poorest with respect to profitability and risk. In many farm decision situations, switching to a higher profit alternative comes at the cost of 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 case, 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 a serious problem, 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 long-term sustained profitability: (1) nitrogen is supplied for future wheat crops through the break down of plant material and animal waste, (2) soil organic matter is elevated which increases the soil's water holding capacity, nutrient levels and beneficial microorganisms, and (3) soil cover is better, preventing more erosion.

Although lower yields were generally noted with wheat following grazed Austrian winter pea over the study period, soil quality improvements over a longer period of time may very well serve to reduce or eliminate these yield reductions. Added benefits of pea-grazed fallow were also limited in this study by a rather high cost of establishing Austrian winter pea ($20 per acre), and a relatively short time-span (3-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 extended rotations, 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. Their business survival 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 the following June of each 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 (1996) 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] For the 6-year period of observed yields in Table 1 (1995, 1997-2001), wheat yields from the 4-year rotation study ($W_{s\text{-}m\text{-}f}$) were found to be highly correlated (0.923 and 0.886) with wheat yields in the Austrian Winter Pea study (W_f and W_P). For the years 1988-94 and 1996 (hail), wheat yields for these two rotations (W_f and W_P) were estimated with linear regression, using wheat yield data ($W_{s\text{-}m\text{-}f}$) from four-year rotation study, (1995, 1997-2001) as the independent variable (x); and respective wheat yields for wheat-fallow (W_f) and wheat-graze pea (W_P), for the same years (1995, 1997-2001) as dependent variables (R^2 =0.85 and 0.73 respectively).

[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. Lower average yield (29 vs. 32 bu/ac) from wheat following Austrian winter pea, 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 significanat, p = 0.05.

[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% 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.

[9] The year 2001 was among the poorest for profitability (negative rates of return) over the 14-year period due to an unfortunate combination of below average crop yields and below average prices. Net return for earlier years is computed in the same format shown in Table 5, using earlier yields and prices.

[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 (Table3) using the format illustrated in Table 5. 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 (e.g., 0%), the cumulative probabilities in Table 7 provides the same information for a series of multiple targets, ranging from -10% to +28%.

[13] 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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Table 1. Annual yields for dryland crops in southeast Wyoming, 1988-2001.

	Four-year rotation study[1]			Wheat-pea study[2]		County yield[3]
Years	**Wheat (W_{s-m-f})**	**Sunflowers (S)**	**Millet (M)**	**Wheat (W_f)**	**Wheat (W_P)**	**Wheat ($W_{L-Co.}$)**
	bu/acre	cwt/acre	cwt/acre	bu/acre	bu/acre	bu/acre
1988	38	14.0	12.0	***39***	***34***	27
1989	25	9.0	10.0	***26***	***25***	20
1990	34	12.0	14.0	***35***	***32***	30
1991	30	16.5	15.0	***31***	***29***	30
1992	21	8.0	10.0	***23***	***23***	26
1993	32	11.5	25.0	***33***	***30***	29
1994	26	6.0	11.0	***27***	***26***	22
1995	60	8.5	12.0	57	47	37
1996	***34***	***13.0***	10.0	**35**	**31**	27
1997	22	17.0	18.0	29	33	32
1998	27	13.5	17.5	19	22	30
1999	42	16.5	22.0	52	42	31
2000	23	7.0	14.5	25	22	19
2001	19	9.5	16.0	19	17	20
Avg.	31	11.6	14.8	32	29	27
Std. dev.	11	3.7	4.6	11	9	5
CV	0.355	0.319	0.311	0.344	0.310	0.185

[1] Unpublished yield data for wheat (W_{s-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 (W_f) and wheat-graze pea (W_P), 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 (W_{s-m-f}) from the 4-year rotation study, (1995, 1997-2001) as the independent variable; and respective wheat yields for wheat-fallow (W_f) and wheat-graze pea (W_P), 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.).

Table 2. Yield correlation for selected crops in southeast Wyoming, 1988-2001.[1]

Crops:	**W_{s-m-f}**	**S**	**M**	**W_f**	**W_P**	**$W_{L-Co.}$**
W_{s-m-f}	**1.000**	0.130	0.025	0.932	0.894	0.700
S	--	**1.000**	0.467	--	--	--
M	--	--	**1.000**	--	--	--
W_f	--	--	--	**1.000**	0.967	0.661
W_P	--	--	--	--	**1.000**	0.774
$W_{L-Co.}$	--	--	--	--	--	**1.000**

[1] W_{s-m-f} is wheat in a four-year rotation with sunflowers (S), millet (M) and fallow (f); W_f is wheat in a wheat-fallow rotation; W_p is wheat in a wheat-graze pea rotation; and $W_{L-Co.}$ is wheat yield for Laramie County in southeast Wyoming.

Table 3. Annual prices for crops and lambs, 1988-2001.[1]

Years	Products				
	Wheat [2] (W_f)	Wheat [3] (W_P)	Sunflowers [4] (S)	Millet [5] (M)	Lambs [6] (L)
	------------$/bu---------		-------------------$/cwt------------------		
1988	4.37	4.45	12.96	7.87	77.84
1989	4.50	4.51	11.47	6.64	85.34
1990	2.80	2.86	11.64	4.97	63.36
1991	3.03	3.04	8.71	3.64	61.43
1992	2.95	3.11	10.00	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	94.30
1996	4.41	4.42	11.52	5.86	101.24
1997	3.44	3.67	11.33	4.45	89.54
1998	2.30	2.85	10.59	4.23	94.26
1999	2.44	3.15	7.31	4.00	87.37
2000	2.34	2.62	6.48	9.53	89.22
2001	2.70	2.85	8.08	4.15	75.00
Avg.	3..33	3.55	10.46	5.93	80.83
Std. dev.	0.83	0.74	2.08	1.95	12.73
CV	0.249	0.208	0.200	0.329	0.157

[1] Product prices are converted to a 2001 real dollar basis, using the Producer Price Index.
[2] Price for wheat produced after conventional fallow (W_f) is Wyoming summer price at harvest (Wyo. Agric. Stat.).
[3] Price for wheat produced after grazed peas (W_P) 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.)

Table 4. Correlation of product prices, 1988-2001.

Products	Products: Wheat	Sunflowers	Millet	Lambs
Wheat	**1.000**	0.661	0.272	0.278
Sunflowers		**1.000**	0.218	-0.073
Millet			**1.000**	0.049
Lambs				**1.000**

Table 5. Net return (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)	19 bu	--	19 bu	--	--
• price (per unit)	$2.70	--	$2.70	--	--
Total ($/ac) [1]	51.30	0	51.30	0	25.65
Costs ($/ac) [2]	49.49	42.16	49.49	42.16	45.83
Net return ($/ac)	1.81	-42.16	1.81	-42.16	-20.18
Rate of return [3]	--	--	--	--	**-8.1 %**
(2) W-P-W-f	Wheat	Pea	Wheat	Fallow	**Average**
Returns					
• yield (per acre)	19 bu	35 lbs	17 bu	--	--
• price (per unit)	$2.70	$0.75	$2.85	--	--
Total ($/ac) [1]	51.30	26.25	48.45	0	31.50
Costs ($/ac) [2]	49.49	55.65	48.72	42.16	49.00
Net return ($/ac)	1.81	-29.40	-0.27	-42.16	-17.50
Rate of return [3]	--	--	--	--	**-7.0 %**
(3) W-S-M-f	Wheat	Sunflower	Millet	Fallow	**Average**
Returns					
• yield (per acre)	19 bu	9.50 cwt	16.0 cwt	--	--
• price (per unit)	$2.70	$8.08	$4.15	--	--
Total ($/ac) [1]	51.30	76.76	66.40	0	48.62
Costs ($/ac) [2]	45.68	96.35	63.68	42.16	61.97
Net return ($/ac)	5.62	-19.59	2.72	-42.16	-13.35
Rate of return [3]	--	--	--	--	**-5.3 %**
(4) W-S-M-P	Wheat	Sunflower	Millet	Pea	**Average**
Returns					
• yield (per acre)	17 bu.	9.50 cwt	16.0 cwt	35 lbs	--
• price (per unit)	2.85	$8.08	$4.15	$0.75	--
Total ($/ac) [1]	48.45	76.76	66.40	26.25	54.47
Costs ($/ac) [2]	44.91	96.35	63.68	55.65	65.15
Net return ($/ac)	3.54	-19.59	2.72	-29.40	-10.68
Rate of return [3]	--	--	--	--	**-4.3 %**

[1] Crop returns are the product of respective 2001 yields (Table 1) and 2001 prices (Table 3). Pea grazing income in 2001 ($26.25/acre) is based on a wheat grower receiving 35% of the value of a 100 lb. lamb gain (35 lb.) times 2001 lamb price ($0.75/lb).

[2] Detailed cost budget 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.

Table 6. Annual and 14-year average (1988-2001) rates of return to land, and selected measures of variability and risk, given alternative crop rotations.

	Crop rotations[1]			
Items:	**(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	13.0	17.6	17.7
1989	4.0	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	21.0
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	15.0
1998	-9.5	-5.6	2.5	4.9
1999	4.2	6.8	5.0	9.6
2000	-7.1	-5.3	-1.4	0.8
2001	-8.1	-7.0	-5.3	-4.3
Avg. (%)	2.3	3.6	5.6	7.3
Std. dev. (%)	10.1	9.3	8.1	7.8
CV	4.423	2.554	1.436	1.068
Years (in 14) < 0.0 %	7 / 14	5 / 14	3/ 14	2 / 14

[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 for year 2001, are illustrated for each rotation in Table 5.

Table 7. 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%	**0.50**	**0.36**	**0.21**	**0.14**
2%	0.64	0.50	0.29	0.29
4%	0.71	0.57	0.50	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 6.

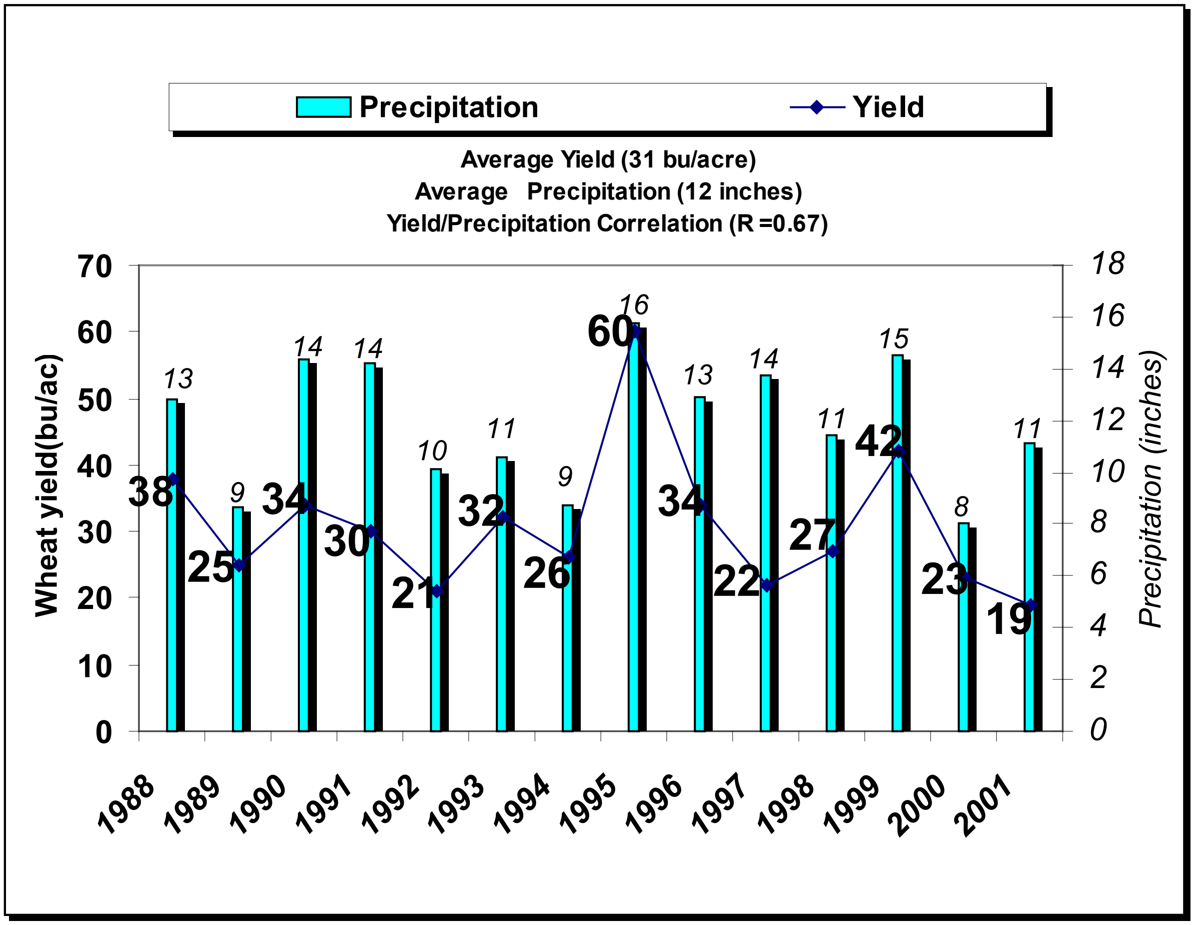

Figure 1. Annual wheat yield and growing season precipitation (September-June) at the Archer Research and Extension Center in southeast Wyoming, 1988-2001.

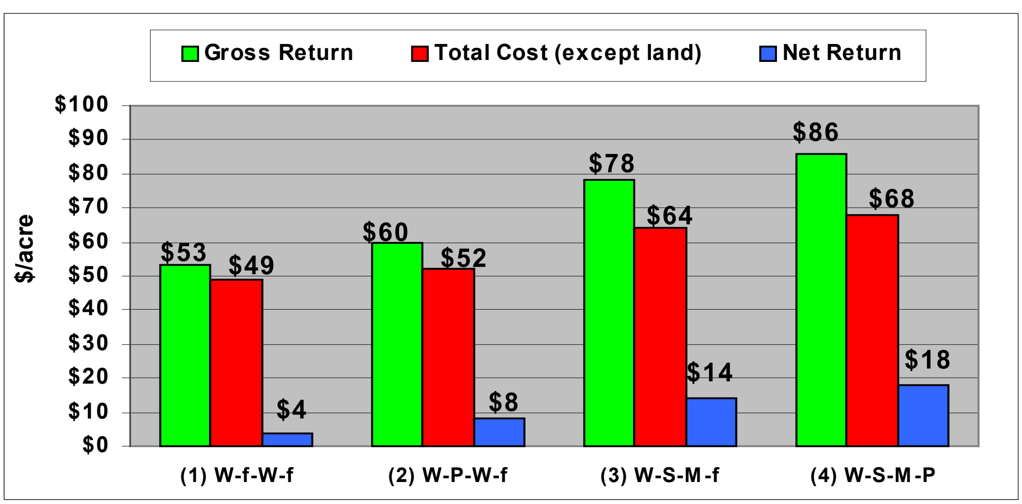

Figure 2. Per acre gross return, cost (except land) and net return associated with different dryland rotations, given average crop yields and prices, 1988-2001.

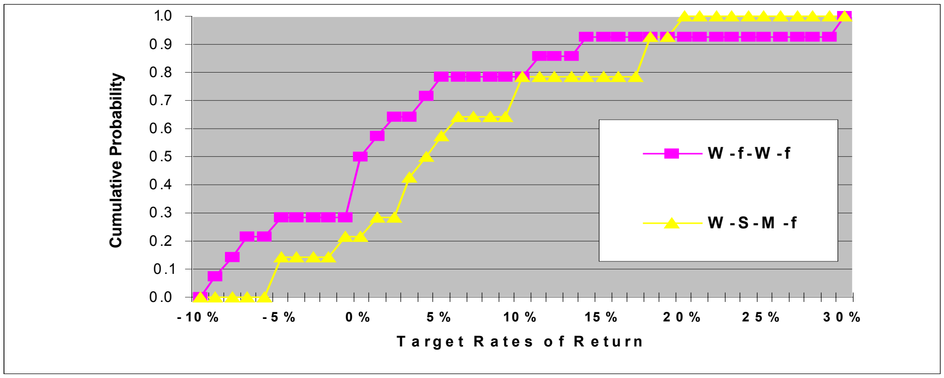

Figure 3. Probability that percentage rates of return will fall below specified targets, given two alternative crop rotations: (1) W-f-W-f vs. (2) W-P-W-f.

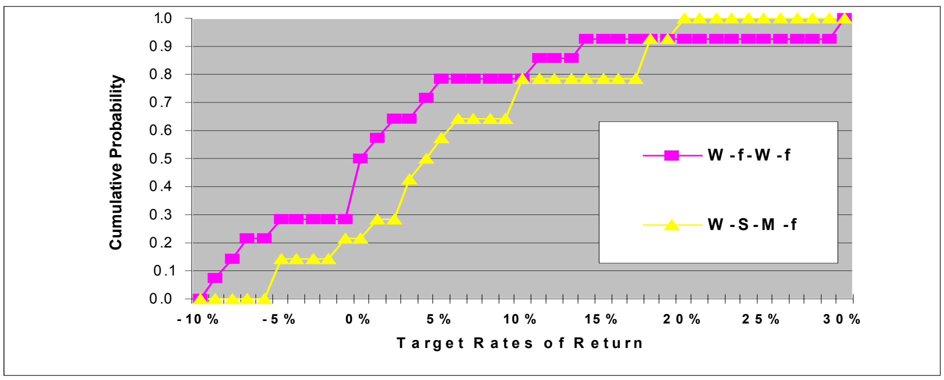

Figure 4. Probability that percentage rates of return will fall below specified targets, given two alternative crop rotations: (1) W-f-W-f vs. (3) W-S-M-f.

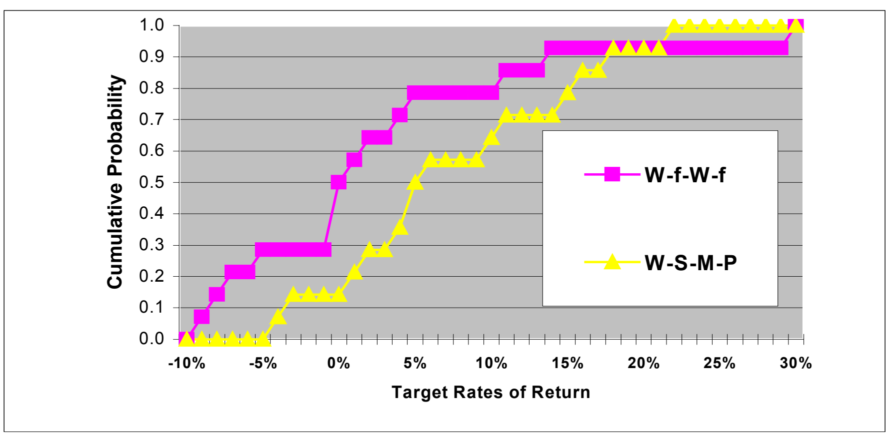

Figure 5. Probability that percentage rates of return will fall below specified targets, given two alternative crop rotations: (1) W-f-W-f vs. (4) W-S-M-P.