Agricultural Marketing Policy Center MSU - Bozeman

BRIEFING

Briefing No. 5 November 2001

Economics Considerations of Expanding Crop Rotations

James B. Johnson and Gary W. Brester

Agricultural Marketing Policy Center
Linfield Hall
P.O. Box 172920
Montana State University
Bozeman, MT 59717-2920
Tel: (406) 994-3511
Fax: (406) 994-4838
email: ampc@montana.edu
website: www.ampc.montana.edu

Contact:
James B. Johnson
(406) 994-5606
jamesjohnson@montana.edu
Gary W. Brester
(406) 994-7883
gbrester@montana.edu

Objective Analysis for Informed Decision Making

Introduction:

In areas where all farmland is generally in crop in each production year, expanding crop rotations is accomplished by substituting acreage of an alternative crop for some acreage of an existing crop. In areas where summer fallow is included in the rotation, expanding crop rotations can occur through substitution of alternative crop acreage for some acreage of an existing crop or increasing farmland use intensity by planting an alternative crop on land that would have otherwise been fallowed.

Three primary economic considerations are important when a farm manager is contemplating the expansion of a crop rotation through the introduction of an alternative crop. Will the alternative crop be a profitable enterprise? Will the introduction of an alternative crop result in some positive rotation impact, perhaps best represented as an increase in net farm income? And will the introduction of an alternative crop result in economic diversification, providing the same net farm income with less year-to-year variability or an increased level of net farm income in conjunction with an acceptable increase in income variability?

Enterprise Profitability:

Enterprise profitability is often assessed through an enterprise budget that is a projection of the average costs and returns on the basis of some common unit such as an acre. Farm managers in the semi-arid areas of the Northern Plains have historically made at least implicit assessments such as whether winter wheat after fallow or spring wheat after fallow would be most profitable. In the higher precipitation areas of the Northern Plains, farm managers have assessed the relative profitability of crops such as corn and soybeans.

Farm managers can develop enterprise budgets to assess the expected profitability of alternative crops. Table 1 presents a hypothetical enterprise budget for “exotic peas” (a hypothetical crop) produced on an acre of stubble.

In this example case, exotic peas are a profitable enterprise. The peas would fully compensate the expected operating costs and cover machinery ownership costs. However, are exotic peas a more profitable crop than an existing enterprise? Would the substitution of exotic peas for some of the crops in the existing rotation improve net farm income, on average?

Rotation Impact:

Will introducing exotic peas into the rotation increase net farm returns, on average? To address this question, the farm manager will need some measure of net farm returns for the existing rotation. Consider the following example (Table 2) of a cash grain farm in a semi-arid production area.

Expected net farm income from the existing rotation provides the basis for evaluating farm income if an alternative crop was introduced into the rotation. The exotic peas enterprise budget indicates that peas would be a profitable crop. Would it be reasonable to incorporate exotic peas or some other alternative crop into the traditional rotation?

Producers may have agronomic and pest management incentives for expanding crop

Table 1: Enterprise Budget for Exotic Peas

Expected Gross Income:	Unit	Expected Price	Expected Yield (lbs/acre)	Amount
Exotic Peas	lbs.	$0.06	1,800	$108.00
Expected Operating Costs:	Unit	Price	Quantity	Amount ($)
Herbicide for burn down Seed and treatment Fertilizer, 11-52-0 Post-emergence herbicide Machinery operating costs Interest on operating costs	lbs. lbs. tons ounce acre acre	$1.00 0.09 266.00 1.13 19.30	7.50 135.00 0.04 8.00 1.00	7.50 12.42 10.64 9.00 19.30 2.94
Total Operating Costs				61.80
Machinery Operating Costs				28.28
Operating Costs plus Machinery Ownership Costs				90.08
Expected net returns above Operating Costs and Machinery Ownership Costs				17.92

Table 2: Returns above Operating Costs and Machinery Ownership Costs for a Cash Grain Farm

Land Use	% of Acres	Acres	Net Returns per Acre ($)	Net Returns per Crop ($)
Winter Wheat after fallow	11	220	55.75	12,265
Winter Wheat on stubble	6	120	36.46	4,375
Spring wheat after fallow	26	520	59.03	30,696
Spring wheat on stubble	5	100	28.73	2,873
Barley after fallow	5	100	33.92	3,392
Barley on stubble	5	100	13.44	1,344
Fallow	42	840	(19.63)	(16,480)
Farm Net Returns				38,465
Net Returns per Acre			19.23	
Total Acres	100%	2,000		

rotations. Continuous or near continuous planting of cereals may lead to buildups of pest problems. Incorporating alternative crops into existing rotations may breakup these pest cycles. Reductions in disease, insect and weed management costs for the cereal crops maintained in these expanded rotations are sometimes substantial. Additionally, the inclusion of nitrogen-fixing crops into traditional rotations may lead to reductions in applied nitrogen fertilizer costs for subsequent crops. Some experience with the expanded rotation is required to determine if cost savings will accrue.

In this example, exotic peas appear more profitable than feed barley even without considering longer-term rotation interactions that might eventually give rise to cost savings or increased revenues. Consider the initial expected net farm income level with exotic peas substituted for barley produced on stubble, the least profitable enterprise in the existing rotation. If more acres of exotic peas were considered desirable in this rotation, the acres next most likely to be considered for exotic pea production would be those allocated to spring wheat on stubble.

With the substitution of exotic peas for barley produced on stubble, average expected per acre and farm-level net returns would remain about the same. (Table 3). Although net farm income is expected to be about the same with the

Table 3: Returns above Operating Costs and Machinery Ownership Costs of a Cash Grain Farm with Dry Peas incorporated in the Rotation

Land Use	% of Acres	Acres	Net Returns per Acre ($)	Net Returns per Crop ($)
Winter Wheat after fallow	11	220	55.75	12,265
Winter Wheat on stubble	6	120	36.46	4,375
Spring wheat after fallow	26	520	59.03	30,696
Spring wheat on stubble	5	100	28.73	2,873
Barley after fallow	5	100	33.92	3,392
Exotic peas on stubble	5	100	17.92	1,792
Fallow	42	840	(19.63)	(16,480)
Farm Net Returns				38,913
Net Returns per Acre			19.46	
Total Acres	100%	2,000		

Table 4: Per Acre Variance for the Gross Income of Crop 1

Year	Spring Wheat Yield	Spring Wheat Price	Y_1	$\overline{Y_1}$	$Y_i - \overline{Y_1}$	$(Y_i - \overline{Y_1})^2$
1995	43	$4.59	$197	$131	66	4,356
1996	31	$4.15	$129	$131	-2	4
1997	0	na	87*	$131	-44	1,936
1998	35	$3.13	$110	$131	-21	441
Total			$523			6,737
Mean			$523/4=$131			
S_1^1						6,737/3=2,245

na-not applicable because there was no yield
* is the per acre crop insurance indemnification

substitution of exotic peas for some barley production on this farm, will net farm income be more or less variable?

Economic Diversification

Effective economic diversification through rotation expansion occurs when farm-level net returns are maintained with a reduced level of variation. Economic diversification also occurs when farm-level net returns are increased with an acceptable increase in the level of income variation with the expanded rotation.

To reduce the burden of arithmetic associated with variance calculations, a farm that has only one crop, spring wheat produced after fallow, will be considered initially. Average annual farm-level income variability will be calculated. (Table 4) Then a second crop, exotic peas after fallow, will be included in the rotation and the average farm-level income and variance recalculated.

How is the variance in the farm-level income calculated? If there is only one crop involved, the variance in farm-level income is $V(K_1 Y_1)=K_1^2 S_1^2$, where Y_1 denotes the gross income from one acre of crop Y_1; K_1, denotes the acres in crop 1 and S_1^2 denotes the per acre variation in income of crop Y_1.

The per acre variance for the gross income of crop 1 is:

$$S_1^2 = \sum_{i=1}^{n} (y_i - \bar{y}_1)^2 / (n - 1)$$

where $\overline{Y_1}$ is the mean or average income for crop 1 and n is the number of years of observation for the income of crop Y_1. The per acre variance measures the dispersion of actual per acre incomes around the mean per acre income.

On the 2,000 acre farm, assume 1,000

acres planted to spring wheat each year with the remaining 1,000 acres in fallow. The farm's only source of gross income is from spring wheat. Suppose the farm manager had four years of information on producing spring wheat after fallow. In 1997, a total crop failure occurred. But, the farm carried crop insurance on the spring wheat, so an indemnity of $87 per acre was received. The mean annual gross income was $131 per acre over the four year observation period and the per acre variance in gross income was estimated to be 2,245.

If all the non-fallowed land was planted to spring wheat, the average annual farm level gross income is $131,000=($131 per acre) x (1,000 acres). Under this scenario the variance calculation for the farm-level income is $V(K_1 Y_1)=K_1^2 S_1^2$=(1,000 acres)^2 x (2,245 per acre) = 2,245,000,000.

Consider the same farm under a different scenario. The producer wants to plant two crops rather than one, and has been experimenting with the production of exotic peas on a few acres each year. So the producer considers a scenario with 500 acres of spring wheat after fallow, 500 acres of exotic peas after fallow, and 1,000 acres of fallow.

The farm level variance calculation for gross farm income when two crops are considered is: $V(K_1Y_1+K_2Y_2)=K_1^2S_1^2+K_2^2S_2^2+2K_1K_2S_{12}$. S_2^2 is the per acre variance for exotic peas. The covariance, S_{12}, measures the association of the acre gross incomes for the two crops. The estimated covariance is:

$$S_{12}=\sum_{i=1}^{n}[(y_{1i}-\bar{y}_1)(y_{2i}-\bar{y}_2)]/(n-1)$$

where n is the number of paired observations.

The per acre variance in the gross income for exotic peas, S_2^2, is calculated in Table 5.

The covariance calculation, S_{12}, for this two crop rotation is shown in Table 6.

Under this scenario, the expected average annual farm-level gross income is ($131 per acre of wheat) x (500 acres of wheat) +($139 per acre of exotic peas) x (500 acres of peas) = $135,000.

The farm level income variation, $V(K_1Y_1+V_2K_2)$=(500 acres of wheat)^2 x (2,245 per acre variation in wheat income) + (500 acres of exotic peas)^2 x (9,124 per acre variation in exotic pea income) + 2 x (500 acres of wheat x 500 acres of exotic peas) x (3,432 per acre covariance)=4,558,250,000.

Summary of Farm-Level Income and Income Variability

Under these crop rotation scenarios the estimated average annual farm-level gross incomes and their variances are reported in Table 7**.**

Table 5: Per Acre Variance for the Gross Income of Crop 2

Year	Pea Yield	Pea Price	Y_2	$\overline{Y_2}$	$Y_i - \overline{Y_2}$	$(Y_i - \overline{Y_2})^2$
1995	2,400	$0.09	$216	$139	$77	5,929
1996	2,000	0.08	160	139	-21	441
1997	0	0.13	0*	139	-139	19,321
1998	1,800	0.10	180	139	41	27,372
Total			$556			
Mean			$556/4=$139			
S_2^2						27,372/3=9,124

*There is no crop insurance actuarial table available for this crop in the subject county. The farm manager took no other actions to manage production risks.

Table 6: Covariance between the Gross Incomes of Crop 1 and Crop 2

Year	$Y_1 - \overline{Y_1}$	$Y_2 - \overline{Y_2}$	$(Y_1 - \overline{Y_1})(Y_2 - \overline{Y_2})$
1995	$66	$77	5,082
1996	-2	21	-42
1997	-44	-139	6,116
1998	-21	41	-861
Total			10,295/3=3,432

A farm manager may not be willing to accept more than double the variation in farm income for an increase of only $4,000 in gross farm income,(a 3 percent increase). This example illustrates that when a farm manager decides to expand from a single crop to a two crop rotation, it does not necessarily lead to *economic diversification.* The expansion of the rotation from one to two crops may increase net farm income, but also may dramatically increase the variance of farm-level income.

Table 7: Summary of Average Farm Income and Income Variability

Farm Level Income Measure	**All Wheat**	**½ Wheat ½ Exotic Pea**
Average	$131,000	$135,000
Variance	2,245,000,000	4,528,250,000

On this example farm, the farm manager was using crop insurance to manage production risks associated with spring wheat production to reduce income variation. The farm manager had not pursued crop insurance or other means for managing production risk associated with the alternative crop. There are several avenues to pursue in managing production risks associated with alternative corps. These avenues are the addressed in other *Briefings.*

There are other sources of variation in farm-level gross income associated with the introduction of alternative crops into an existing rotation. These are price and business risks. (Again, these are addressed in separate *Briefings).*

Support for the preparation and delivery of materials in this publication was provided by the Montana Agricultural Experiment Station, the MSU Extension Service, the Federal Crop Insurance Corporation through the Risk Management Agency, and the Cooperative State Research, Education and Extension Service of the United States Department of Agriculture.