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Effects of Crop Diversification Upon the Variability of Income for Eastern- Southeastern South Dakota

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THE EFFECTS OF CROP DIVERSIFICATION UPON THE VARIABILITY OF INCOME FOR EASTERN-SOUTHEASTERN SOUTH DAKOTA

D. L. Peterson
Economics Department

Dryland farming in east-southeastern South Dakota[1] is characterized by diversified crop production. Alfalfa, corn, oats, soybeans, and grain sorghum are the most popular crops, accounting for more than 93% of the dryland acres planted in 1975 (Table 1). Flax, barley, rye, alfalfa seed, and hay other than alfalfa were grown on the remaining 7% of the dryland crop acres.

A major reason farmers in this area diversify is for income stability. Diversification evens out the high variability in income associated with specializing in one crop. It is the purpose of this study to investigate the effects of crop diversification upon income level and variability.

[1] East-southeastern South Dakota is defined as Moody, Minnehaha, Clay, Lincoln, Turner, Union, and Yankton counties.

METHOD OF STUDY

Data Sources

Data on county crop yields and prices received by farmers were obtained from annual reports of the South Dakota Crop and Livestock Reporting Service (6). Prices paid for inputs were obtained from the same source whenever possible. However, some information could only be obtained from other sources (7,4,3).

Time Series and Budgets

Net return to management was determined for each crop for years 1964 through 1971 plus the year 1975. Abnormal farm markets characterized 1972 through 1974. Poor crops in the U.S.S.R., China, and elsewhere increased the demand for U.S. produced wheat and feed grain. Greatly reduced anchovy catches increased the demand

Table 1. Acres and percent of land allocated to the most common crops grown in Eastern-Southeastern South Dakota in 1975

Crop	Acres	% of Land
Corn	837,000	48.33
Oats	361,000	20.84
Soybeans	261,700	15.11
Alfalfa	148,000	8.55
Grain Sorghum	8,000	0.46
All Other Crops	116,220	6.71
Total Acres	1,731,920	100.00

for soybeans and other high protein crops. These conditions produced the greatest price increases for farm products in history. Government imposed price freezes also prevented the market from operating normally. For these reasons the years 1972 through 1974 were excluded from the study.

From 1964 through 1972, government price support programs were in effect. Thus with the years 1972 through 1974 dropped from the time series, the only year when a price support program did not exist was 1975. At the time of the writing of this report, it appears that some type of price support program will once again be in effect by 1978, which will likely have the same effects on the variability as did the earlier programs.

The return to labor and management was estimated for each year by subtracting the calculated cost of production and implicit land rent from total revenue. Total revenue was estimated from the product of average yield and the average price received by farmers, as reported by the South Dakota Crop and Livestock Reporting Service (6). The average yield for the east-southeastern counties in each year of the study was obtained by using the equation:

$$(1)\quad Y_B = \frac{\Sigma P_{Bi}}{\Sigma A_{Bi}}$$

Where Y_B is the average yield per acre of crop B, P_{Bi} is the total production of crop B in county i, and A_{Bi} is the total acres of crop B harvested in county i.

This technique was chosen because it weighs the yields of the different sized counties commensurate with their total acres. It should be recognized that this technique estimates the variance of the whole area, rather than of the separate counties. This means the estimate of the variance will be less than would be the case for the individual counties due to offsetting yield changes among the counties within the district in any given year.

Costs of production for each crop were estimated for each year by using "Market Prices for Net Profit, 1975" (2) as a guide for the amount of inputs.[2] It was assumed that there was no appreciable change in technology in the years studied. However, fertilizer use varied considerably, and adjustments were made each year for the amounts of fertilizer used.

An index of fertilizer use was developed, based on total fertilizer sales in South Dakota. The year 1974 had the highest fertilizer sales in history for the state and was equated to the recommendations found in Derscheid and Aanderud (2). All other years were adjusted downward from these recommendations. The costs of fertilizer by year were then calculated using the estimated price and quantity of fertilizer for each respective year.

Drying costs were included in the corn and milo budgets and were based upon custom drying rates per bushel, obtained from Doane's (3) and Duey and Rawson (4).

Production Credit Association and commercial banks make approximately 80% of all non-real estate loans to farmers. Therefore the interest rates used in the study were a weighted average of the rates of these two institutions for non-real estate loans, as reported by the Board of Governors of the Federal Reserve System (1).

Land charges were adjusted from Derscheid and Aanderud (2) by an index number developed from cash rent paid for cropland as reported by the South Dakota Crop and Livestock Reporting Service (6). Since land is assumed to receive the residual profit, any upward or downward trend in profits is capitalized into the price of land.

[2]See Appendix for example of budgets used.

Thus, by including a land charge the variance due to a general rise in prices or increased efficiency would be reduced.

Assumptions

Three important assumptions were made. First, it was assumed that the farm operator had average managerial ability in all possible crops. This is reflected by the use of average yields for the seven-county area.

The second assumption was that land is the limiting resource. Consequently, the results are presented on a per acre basis. If some other input, such as labor, were the limiting resource, then the study should be based on a per hour of labor or other appropriate unit.

The third assumption was that the cost of production does not change with the degree of diversification. If an operator specializes in one crop, more insecticides and herbicides may be required. But offsetting these increases in variable costs is a reduction in the amount of equipment needed to handle other crops. Because of the difficulty in assessing these differences in costs and the fact that they are offsetting, they were ignored in this study.

THEORY

One measure of variability is the variance. The variance is the sum of the squared differences between each of the observations and its mean. In the problem at hand, the variance would be measured in "square dollars" and would not be helpful. Therefore in this report, more attention is given to the standard deviation, which is the square root of the variance. This gives us a measure of variability in dollars per acre.

One element of useful information that can be obtained from the standard deviation is the range of expected income. The range created by adding and subtracting the standard deviation from the mean income will include 68.26% of all observations. For example, suppose the average return per acre for a given crop were $8.00 and the standard deviation were $4.00. This means that in 68 years out of 100 the profit received would be between $12.00 ($8 + $4) and $4.00 ($8 - $4). If two standard deviations were added and subtracted from the mean, 95% of the observation will fall within the range created. Thus, the smaller the standard deviation, the more certain one is of obtaining the expected income.

To use an example, Table 2 shows that soybeans have an expected average income of $10.60 per acre with a standard deviation of $8.98. Applying the above technique, we find that the return to management will be between $19.58 and $1.62 68% of the time and between $28.56 and -$7.36 95% of the time. The smaller the standard deviation, the more accurately you can predict your income.

A problem common to the use of either the variance or the standard deviation as a measure of income variability is that neither is related to the level of income. Thus it is possible to have a low measure of variability combined with either a high income or a low income and likewise for a high measure of variability. To address this problem the coefficient of variation may be used. The coefficient of variation is the standard deviation divided by the expected, or average, income. Thus we obtain the variability per $1.00 of income.

For example, with an expected income of $8.00 and a standard deviation of $4.00, the coefficient of variation would be 0.5. If another crop had an expected income of $8.00 and a standard deviation of 16, the coefficient of variation would be 2, and the income of the second crop would be less secure than that of the first with the chances of a big hit or a big loss being greater for the second crop.

Variability with Two Crops

When two crops, A and B, are grown the total variance is given by the equation:[3]

$$(2)\quad \sigma_T^2 = \sigma_A^2 + \sigma_B^2 + 2\rho\sigma_A\sigma_B$$

where σ_T^2 is the total variance, σ_A^2 is the variance of crop A, σ_B^2 is the variance of B, ρ is the correlation coefficient between A and B, and σ_A and σ_B are the standard deviation of A and B.

When using this formula it is assumed that the size of the operation has increased by the amount of B grown. Under these conditions, the total variance, σ_T^2, would be less than σ_A^2 only if $2P\sigma_A\sigma_B + \sigma_B^2$ is less than zero. For this to occur, the correlation coefficient would have to be negative. If ρ were +1 and $\sigma_A^2 = \sigma_B^2$ then σ_T^2 would increase by 4 times, the same as would be the case if the amount of A were doubled.

The purpose of this study was to find the ratio at which two crops might be grown so as to minimize the variability of income. Therefore the equation (2) above must be modified to a per acre variability and becomes:

$$(3)\quad \sigma_T^2 = q^2(\sigma_A^2) + (1-q)^2\,\sigma_B^2 + 2\rho(q)\,(1-q)\,\sigma_A\sigma_B$$

where q is the proportion of an acre devoted to the production of A and 1-q the proportion devoted to producing B. In equation (3), if the variance of B is not greater than the variance of A, then total variance will be reduced if the correlation coefficient is less than 1, and some of B is grown.

With the use of calculus, the equation for q, denoted as q*, which will result in the minimum variance per acre is:

$$(4)\quad q^* = \frac{\sigma_B^2 - \rho\sigma_A\sigma_B}{\sigma_A^2 + \sigma_B^2 - 2\rho\sigma_A\sigma_B}$$

If the farm operator chooses q* to be the proportion of crop A to be grown, he would be following the most conservative alternative available.

However the problem arises that was discussed with respect to the standard deviation above: what about the level of income? It is entirely possible that the point where the variance and standard deviation are minimized may involve a very small or even negative profit.

Because equation (3) above does not allow for the evaluation of the level of income, it is well to look at the coefficient of variation, also referred to as the coefficient of net income variation by Johnson and Tefertiller (5). The value for q, denoted as q**, which will result in the minimum relative net income variation for any farm size is given by the equation:

$$(5)\quad q^{**} = \frac{\sigma_B^2 I_A - \rho\sigma_A\sigma_B I_B}{\sigma_A^2 I_B + \sigma_B^2 I_A - \rho\sigma_A\sigma_B(I_A+I_B)}$$

where I_A and I_B are the average income expected per acre for A and B respectively. It also follows then that the total income (I_T) from an acre is:

$$(6)\quad I_T = qI_A + (1-q)\,I_B$$

Effects of Diversification

By plotting the estimate of the standard deviation along the horizontal axis and the average expected income on the vertical axis of a graph, the advantages or disadvan-

[3]For derivation of equations 2 through 6 see Johnson and Tefertiller (5).

tages of diversification become clearer.

Consider Figure 1. This illustrates the power of diversification in reducing variability in income per acre. As some land is moved into the production of B and away from A, income is increased and risk is reduced until 50% of the available land is devoted to each crop. Thus it would be irrational for a producer to devote more than 50% of his land to growing A. Just how much land in excess of 50% should be used to produce crop B depends upon the operator's willingness to accept risk to gain more income.

It is possible that there may be additional costs associated with diversification. Economies of scale may be lost, additional machinery may be needed, or specialized labor may be required. This may reduce expected profits below those for either crop alone (Figure 2). Diversification under such conditions would be most likely for the smaller operators. But for a person who may be forced out of business by one adverse year, a lower but more secure level of income may be desirable.

Another possible outcome is illustrated in Figure 3. As activity B is added to A, both income and variability per acre are reduced until all of B is produced. Under such circumstances the operator would select the combination of A and B on the basis of his willingness to sacrifice income for stability.

A fourth possible outcome is that adding a second crop will result in both higher risk and reduced income, as shown in Figure 4. Under such circumstances, diversification would not be rational.

RESULTS

Returns to management for the years studied are presented in Table

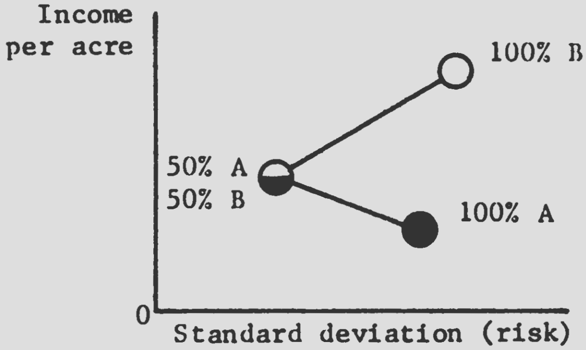

Fig. 1. Combining two high-risk crops may stabilize income somewhere between expected profits for either alone.

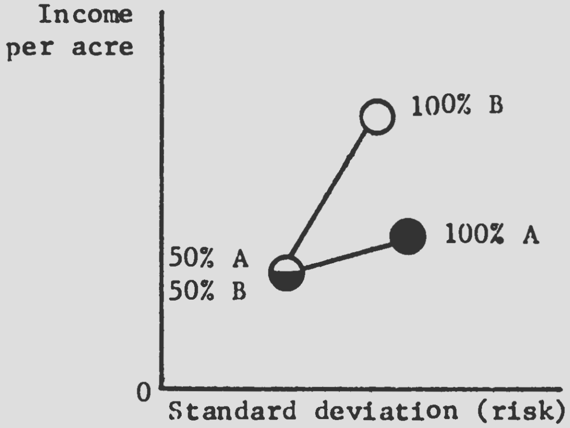

Fig. 2. Combining two crops may reduce both profits and variability expected from either alone.

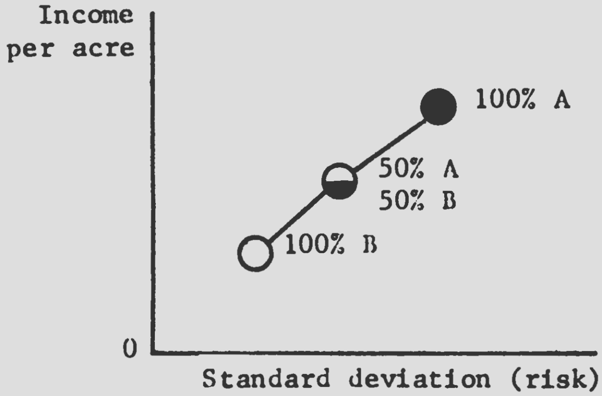

Fig. 3. Combining a high-risk and a low-risk crop is a matter of balance between income and stability.

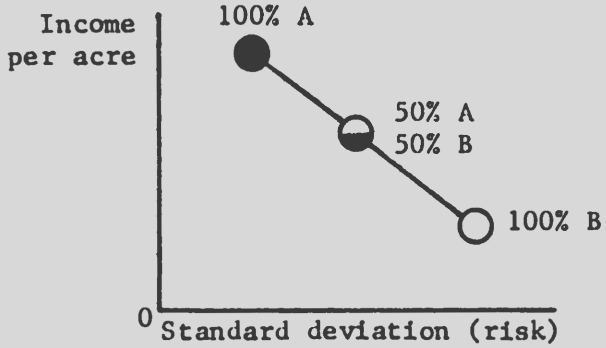

Fig. 4. Adding a low-income, high-risk crop to one already high-income, low-risk is not rational.

2. If the crops are ranked in order of increasing profitability, they are also ranked in order of increasing standard deviation. This means that the higher the expected profit, the greater the variation in income and expected cash flow. For example, soybeans, the most profitable crop, has a standard deviation of almost 9; while oats, the least profitable crop, has a standard deviation of 5.7. Thus one can more closely predict the returns from oats than from soybeans.

We also can readily see the relative profitability of each individual crop. Soybeans were the most profitable with an average income of \$10.54. But soybeans also had the highest standard deviation of 8.979. Despite the high standard deviation soybeans had only one year in the 9 with a net loss to management. This is reflected in the low coefficient of variation of .852. Therefore, you can expect that 68% of the time the income from soybeans will be between \$19.52 and \$1.56 (or an 85.2% fluctuation in either direction from the average).

Alfalfa was the next most profitable crop with an average income of \$6.33 per acre. The variance for alfalfa hay was 7.86 and the coefficient of variation 1.242. Consequently, 68% of the time the income from alfalfa can be expected to be between \$14.19 and -\$1.53 (or a 124.2% fluctuation in either direction from the average). Due to the higher coefficient of variation a negative return is expected to occur more often than with soybeans, as is the case. In 2 of the 9 years in the sample, the return to alfalfa was negative.

Oats had the lowest profitability record with no profit shown in any of the years studied. The average loss was \$16.53 per acre. Because the average net income is negative and the coefficient of standard deviation is small (0.345) there is less than one chance in 500 that oats will produce a profit, assuming that these years used in the study are representative of the future.

Grain sorghum, or milo, like oats had an average return to management which was negative but not as severe as oats. The average income from milo was a loss of \$4.26 per acre. The

Table 2. Returns to management from various crops, years 1964 - 1971 and 1975 in east-southeastern South Dakota counties.

Crop	1964	1965	1966	1967	1968	1969	1970	1971	1975
Soybeans	10.60	4.69	18.25	2.23	- 2.99	9.06	9.55	16.92	26.52
Alfalfa	3.27	11.14	8.49	1.26	- 0.94	12.24	0.59	- 1.32	22.21
Corn	- 1.68	10.85	12.64	- 0.94	0.07	10.68	- 5.09	- 3.42	- 2.59
Grain Sorghum	2.38	3.17	4.89	- 8.00	-10.38	- 6.98	- 3.27	-11.35	- 8.76
Oats	-18.04	- 9.99	-13.51	-12.25	-22.63	-20.36	-25.51	-17.40	- 9.12

expected range in which 68% of all returns from milo would fall is $2.00 to -$10.52. A loss was incurred in 7 of the 9 years of the time series.

The popularity of a crop seems to be highly independent of either profitability or variability. Corn was the most popular crop in terms of acres planted but was neither the most profitable, nor did it have a low standard deviation, although it did have the smallest standard deviation of those crops with a positive expected return to management. On the other hand, corn had the greatest variability relative to its expected income, as indicated by its coefficient of variation of 3.0.

Oats, despite being the least profitable crop, was second in popularity. It did have the smallest standard deviation of all crops listed, as well as the smallest coefficient of variation. However the latter is negative, indicating a negative expected return from oats.

Third in popularity was soybeans, which was the most profitable crop but which had the greatest standard deviation. Because the profitability was high relative to the standard deviation, soybeans had the lowest positive coefficient of variation of all crops.

Although alfalfa ranked second in profitability, it was only fourth in popularity. The standard deviation of alfalfa was second high, while the coefficient of variation was next to the smallest of those crops with a positive expected net return.

Mean	Variance	Standard Deviation	Coefficient of Variation
10.54	80.628	8.979	0.852
6.33	61.787	7.860	1.242
2.28	49.099	7.007	3.073
- 4.26	39.169	6.259	-1.471
-16.53	32.584	5.708	-0.345

Of the crops reviewed, milo was the least popular. Its average net return over the time period was negative, so you would expect it to be relatively unpopular. Like oats, milo's coefficient of variation was negative although somewhat larger in absolute value. Thus there is no discernible pattern or relationship between popularity of a crop and its profitability or any measurement of its variability.

The correlation coefficients of returns to management among the five crops are presented in Table 3. The maximum value that these numbers can take is 1.00000 which means that there is perfect correlation. That is, if the correlation coefficient between two crops were 1, then when the profit of one is up, the profit for the other is up. Conversely, if one falls in profitability, so will the other.

At the other extreme is a correlation coefficient of the value of -1.00000. A coefficient of -1 is the most desirable when trying to achieve stability by use of diversification because it would mean that when the profit of one crop is down the profit of the other is up by a corresponding amount. If the coefficient were zero, there would be no relationship between the profit of the two crops under consideration.

Oats and alfalfa are the most closely correlated, with a coefficient of more than 0.6. This indicates that the profits of these two crops tend to move in the same direction from one year to the next. Soybeans and milo are the two crops most independent of each other, having a correlation coefficient of only 0.06064. Thus the profits of these two crops have very little relationship with each other.

The coefficient of -0.65880 between corn and soybeans is the most

Table 3. Correlation coefficients of the returns to management between any two of the five crops investigated.

	Alfalfa	Corn	Milo	Oats	Soybeans
Alfalfa	1.00000	0.37747	0.15159	0.60867	0.58570
Corn		1.00000	0.54136	0.29969	-0.65880
Milo			1.00000	0.21649	0.06064
Oats				1.00000	0.38854
Soybeans					1.00000

desirable number found in Table 3 because the negative sign indicates that when the profit of one crop is down the profit of the other is up. Thus these two crops, grown in the same year, offer the greatest potential for reducing fluctuations in returns to management.

Variability Per Acre

Corn and Other Crops

Figure 5 shows graphically the effects of diversification on income and returns per acre as different crops are grown in conjunction with corn. In each case income and the standard deviation were calculated for q = 1.0, .75, .50, .25, 0.0 and q*, where q is the proportion of land allocated to producing corn, and q* is the value for q which will minimize the variability of income. In all cases, the power of diversification in reducing variability of income per acre can be seen. Most noticeable is the effect of adding soybeans to corn production.[4]

By growing 100% corn the operator would have an expected income of $2.28 per acre with a standard deviation of 7.007. If he were to allocate one fourth of his existing land to soybeans, his expected income would rise to $4.34 per acre and the standard deviation would decrease to 4.4770, obviously an improvement in both levels of income and reduction in risk. Income would continue to rise and risk decrease until 61% of the land is allocated to corn and 39% to soybeans.

As more of the land is allocated to soybeans beyond this point, the operator is forced to sacrifice security in order to gain additional income. When the land is allocated 50-50 between corn and soybeans, expected income is $6.41 per acre with a standard deviation of 4.4099. With 100% of the land in soybean production the expected income is $10.54 and the standard deviation 8.9793.

Thus if the farm operator were to produce these two crops it would not be rational to allocate more than 61% of the land to corn because it is possible to increase expected income and reduce risk by growing more soybeans. The expected incomes and associated standard deviations for corn grown in combination with other crops are presented in Table 4.

Notice also in Table 4 the effects of adding milo or oats to corn as a way of diversification. Both of these crops reduce the variability but with a sacrifice of income. A combination of 36% corn and 64% oats will achieve the lowest possible standard deviation with corn but with an expected loss of $9.82 per acre! Obviously one is not interested in

[4]For specific values of income at the various values of q see tables in Appendix A.

certainty if it is certainty of an economic loss.

Soybeans and Other Crops

Figure 6 illustrates the effects of crops other than corn on income and its variability as they are added to a soybean operation. A soybean-alfalfa operation would minimize variability per acre when 34% of the land is allocated to soybeans and 66% to alfalfa. This would involve a $2.77 sacrifice in income per acre when compared to 100% soybeans. Milo could be used to reduce variability even more but at a tremendous cost in forgone profit, with an expected income of less than 50 cents per acre when variability is minimized. Oats would result in an even greater loss in income and less reduction in variability.

Milo, Oats and Alfalfa

There is no way that milo or oats can be combined with alfalfa so as to minimize the standard deviation without reducing expected income to an expected

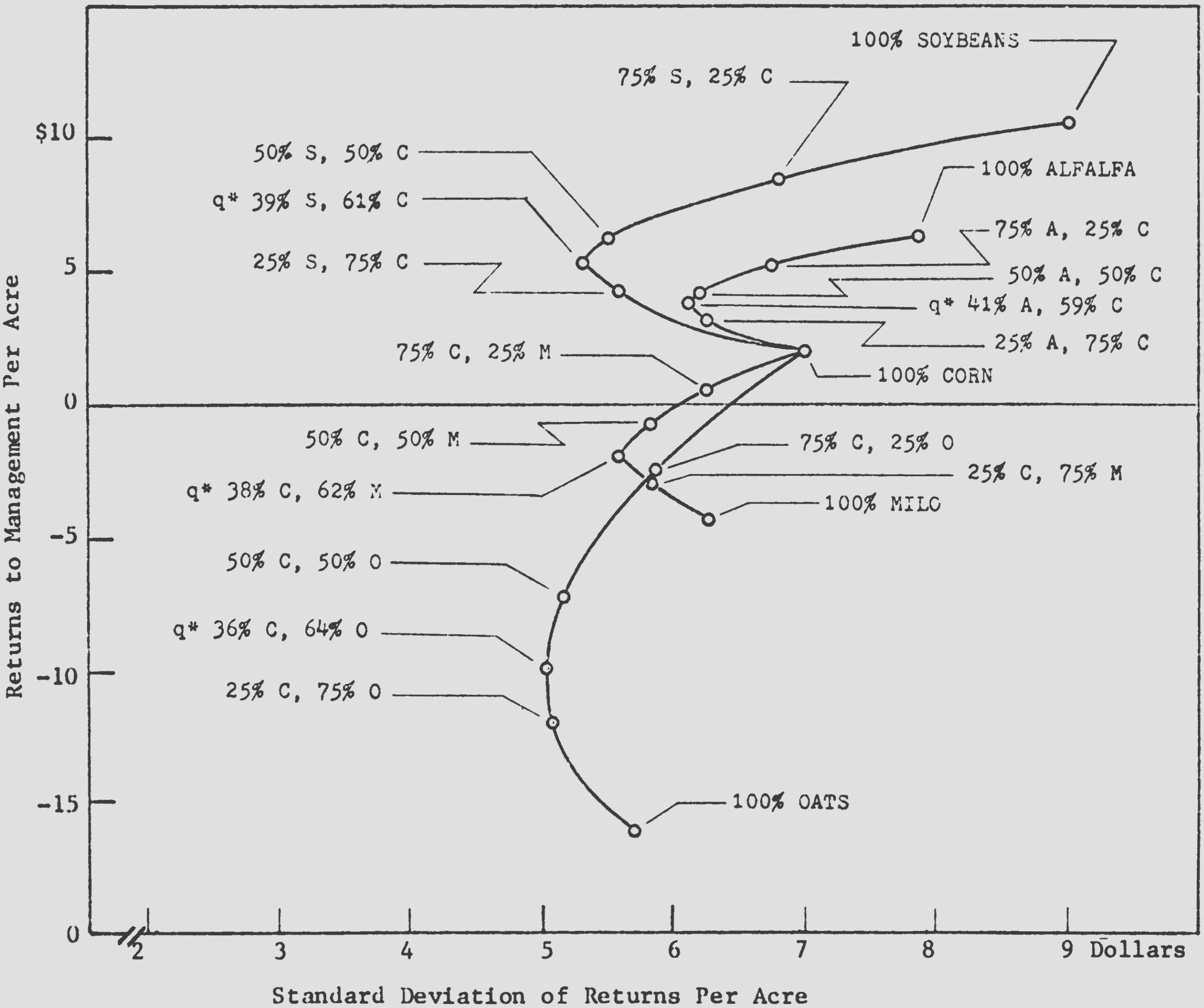

Figure 5.
Income variability as measured by the standard deviation and the return to management per acre for various combinations of soybeans, alfalfa, milo and oats, with corn.

Table 4. Profit per acre for corn, soybeans, alfalfa, oats, and milo and expected profit when diversified to minimize the standard deviation.

Crop	q	1964	1965	1966	1967	1968	1969	1970	1971	1975
Corn	1.00	- 1.63	10.85	12.64	- 0.94	0.07	10.68	- 5.09	3.42	- 2.59
Soybeans	1.00	10.60	4.69	18.25	2.23	- 2.99	9.06	9.55	16.92	26.52
Alfalfa	1.00	3.27	11.14	8.49	1.26	- 0.94	12.24	0.59	- 1.32	22.21
Oats	1.00	-18.04	- 9.99	-13.51	-12.25	-22.63	-20.36	-25.51	-17.40	- 9.12
Milo	1.00	2.38	3.17	4.89	- 8.00	-10.38	- 6.98	- 3.27	-11.35	- 8.76
Corn-Soybeans	.61	3.11	8.45	14.83	0.30	- 1.12	10.05	0.62	8.69	8.76
Corn-Alfalfa	.59	0.35	10.79	10.94	- 0.04	- 0.34	11.32	- 4.85	1.48	7.58
Soybeans-Alfalfa	.34	5.74	8.95	11.81	1.59	- 0.95	11.16	3.64	4.88	23.68
Soybeans-Milo	.32	5.01	3.66	9.17	- 4.73	- 8.02	- 1.85	0.83	- 2.30	2.53
Soybeans-Oats	.17	-13.17	- 7.49	- 8.11	- 9.79	-19.29	-15.36	-19.55	-11.54	- 3.06
Corn-Oats	.36	-12.15	- 2.49	- 4.10	- 7.50	-14.46	- 9.19	-11.02	- 9.90	- 6.77
Oats-Milo	.56	- 9.06	- 4.02	- 5.41	-10.38	-17.24	-14.47	-15.72	-14.74	- 8.96

Note: Other combinations using oats or milo were not included because they resulted in consistent losses and therefore were considered superfluous.

q denotes the proportion of land in the first crop listed of each combination.

loss. This is illustrated in Figure 7. The least desirable value for q* would be a combination of 13% alfalfa and 87% oats, which would result in an expected loss of approximately $12.00 per acre.

Time Series Revisited

Table 4 shows the effects of diversification on income per acre by year for the time series had the crops been grown in such proportions so as to minimize the variation in income per acre. Notice especially the effects of growing corn and soybeans in a 61-39 ratio as compared to growing only one of the two crops. If all corn had been grown, the average income per acre would have been $2.28 over the 9-year period, with a high profit of $12.64 in 1966, and a loss of $5.09 in 1970. In 4 of the 9 years, a loss would have been incurred. If 61% of the land had been allocated to corn and 39% to soybeans, the average income would have been $5.47, with a high of $14.83 in 1966. The only year with a loss would have been 1968, with a loss of $1.12 per acre. On the other hand, if all the land had been allocated to soybeans, the average income per acre would have been $10.54, with a high of $26.52 in 1975 and a low of $2.99 in 1968. Diversification narrows the range in which the expected income will fall.

However, minimizing the variation of income is not the only criterion. Consider a combination of 56% oats and 44% milo. The standard deviation would be reduced to 4.649, which would make it the most predictable income of all possible combinations, but at an expected loss of $11.41 per acre. Furthermore, there is less than seven tenths of one percent chance of even breaking even. This means less than one year in 100 would produce a profit of zero or greater. Because of this low profitability of oats and grain sorghum, several combinations of oats and milo with other crops were not included in Table 4.

Coefficient of Variation

As becomes evident, seeking only to minimize the variability in income

Average	High	Low	Standard Deviation
2.28	12.64	- 5.09	7.007
10.54	26.52	- 2.99	8.979
6.33	22.21	- 1.32	7.860
-16.53	- 9.12	-25.51	5.708
- 4.89	4.89	-11.35	6.259
5.47	14.83	- 1.12	5.344
3.93	11.32	- 4.85	6.127
7.77	23.68	- 0.95	7.402
0.48	5.01	8.02	5.277
-11.93	- 7.49	-19.55	5.513
- 9.76	- 2.49	-14.46	5.023
-11.41	- 4.02	-17.24	4.649

per acre could lead a farmer to choose a combination of crops which would insure a net loss every year. Using the coefficient of net income variation is a technique to cope with this problem. The coefficient of net income variation is the standard deviation divided by the average net income. This calculation gives an expression of the variability per dollar of income. If this number is negative, the expected income is negative, indicating an expected economic loss. Looking at the problem of income stability in this light gives a picture quite different from mini-

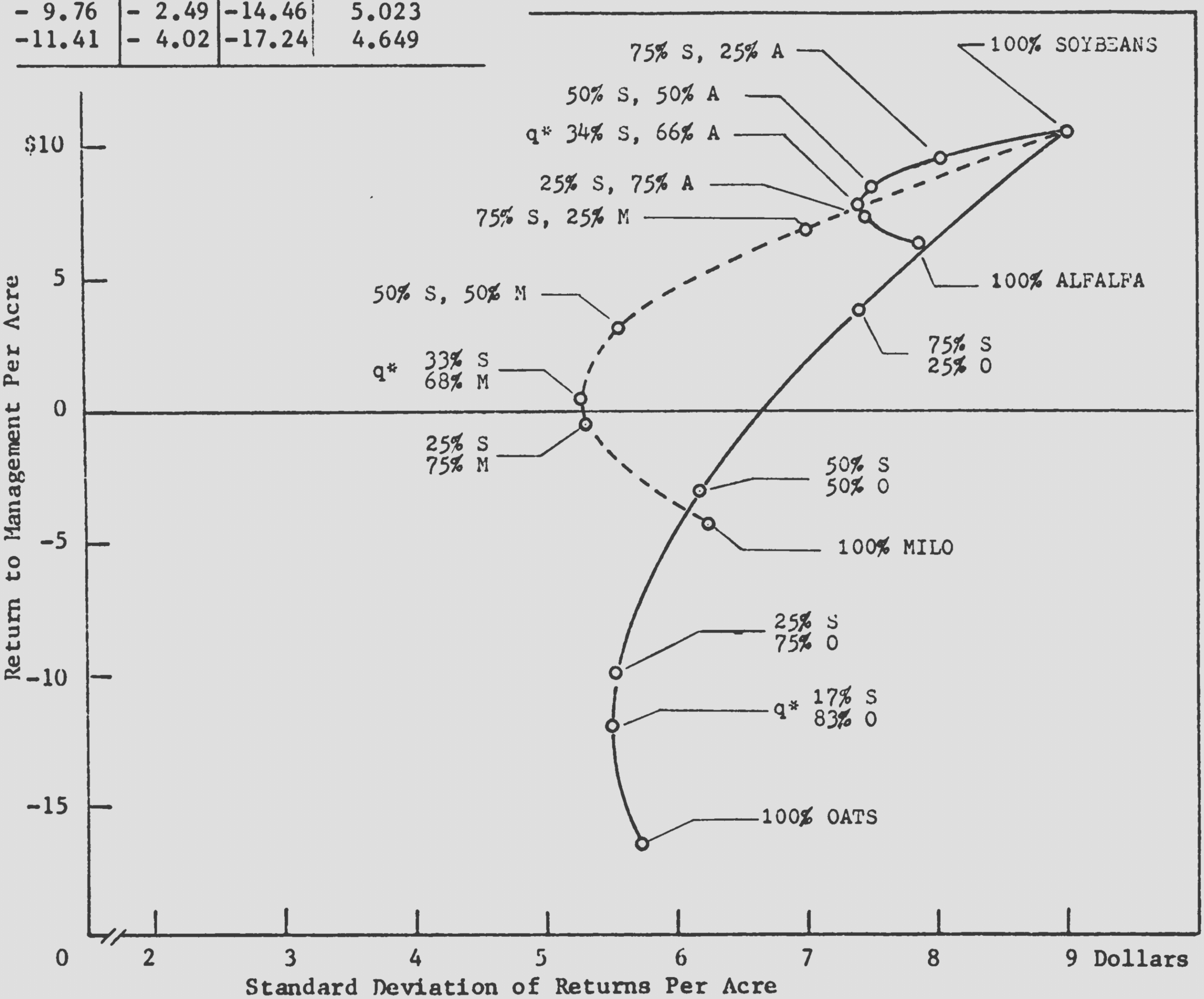

Figure 6.
Income variability as measured by the standard deviation and the return to management per acre for various combinations of soybeans, alfalfa, milo and oats.

mizing the standard deviation. For example, compare Figure 8 with Figure 5.

Soybeans has the lowest variability relative to income of all the crops studied, and this is reflected by its relatively low coefficient of income variability of 0.852. This does not mean that the relative variability of income for a soybean grower cannot be reduced. By adding either corn or alfalfa to the farming operation, the variability of income relative to the level of income can be reduced despite the fact that both corn and alfalfa have a lower income and higher coefficient of income variability. However this increase in stability can be achieved only with a sacrifice in income.

Corn - Soybeans

As is illustrated in Figure 8, if an operator growing only soybeans were to allocate some of his land to corn he could reduce the variability per dollar of net income. This reduction in the coefficient of net income variability could occur until 30% of the land was allocated to corn and 70% to soybeans. At this point, expected income would have fallen from \$10.54 per acre to \$8.10 per acre. However, the variability per \$1.00 of income would also have decreased from 85.22 cents to 80.59 cents.

To allocate more than 30% of the land to corn will result not only in a decrease in income but an increase in variability per dollar of income. Of

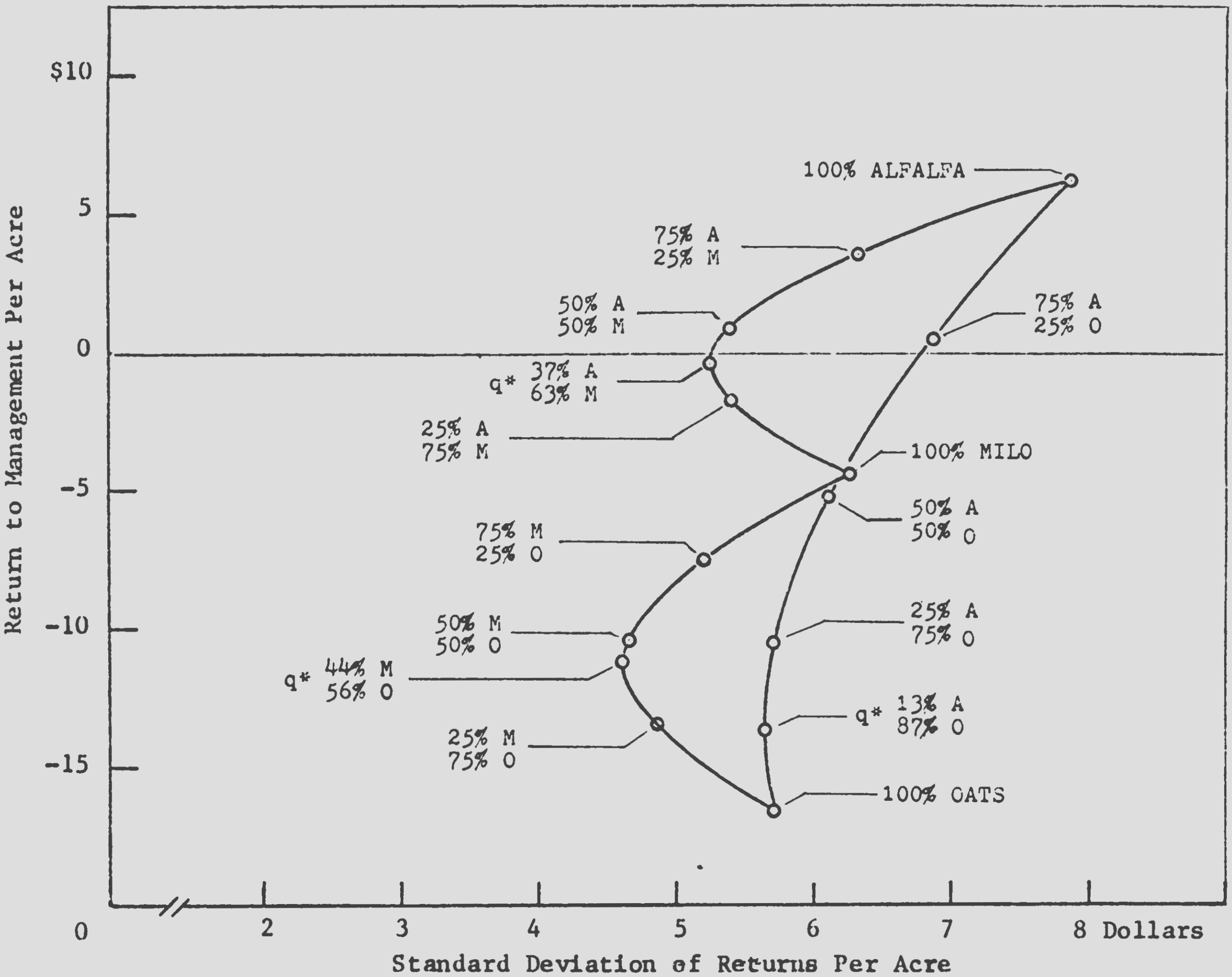

Figure 7. Income variability as measured by the standard deviation and the return to management per acre for various combinations of alfalfa, milo, and corn.

course, looking at this from the point of view of an operator engaged primarily in corn production, both income and security can be increased by adding soybeans to the operation until 70% of the land is allocated to soybean production. Thereafter, additional income will come only with relatively greater risk.

Corn - Alfalfa

Adding corn to a 100% alfalfa program would do little in a practical sense to reduce the coefficient of net income variability. The coefficient of net income variability is minimized when only 3% of the land is allocated to corn, while expected income is reduced from $6.33 per acre to $6.21 and the coefficient of net income variability from $1.2424 to $1.2419 per dollar of income. Thus, for all practical purposes, it appears that adding corn to the operation only reduces net income. As corn is grown on more than 3% of the land, expected income decreases while the coefficient of net income variation increases rapidly, as can be seen in Figure 8.

Alfalfa - Soybeans

By allocating 84% of cropland to soybeans and 16% to alfalfa, the coefficient of net income variation can be reduced to 0.8458 with an expected income of $9.86. This is an improvement over 100% alfalfa, raising expected income by $3.53 per acre and reducing the variability per dollar of income from $1.2424 to $0.8458. The

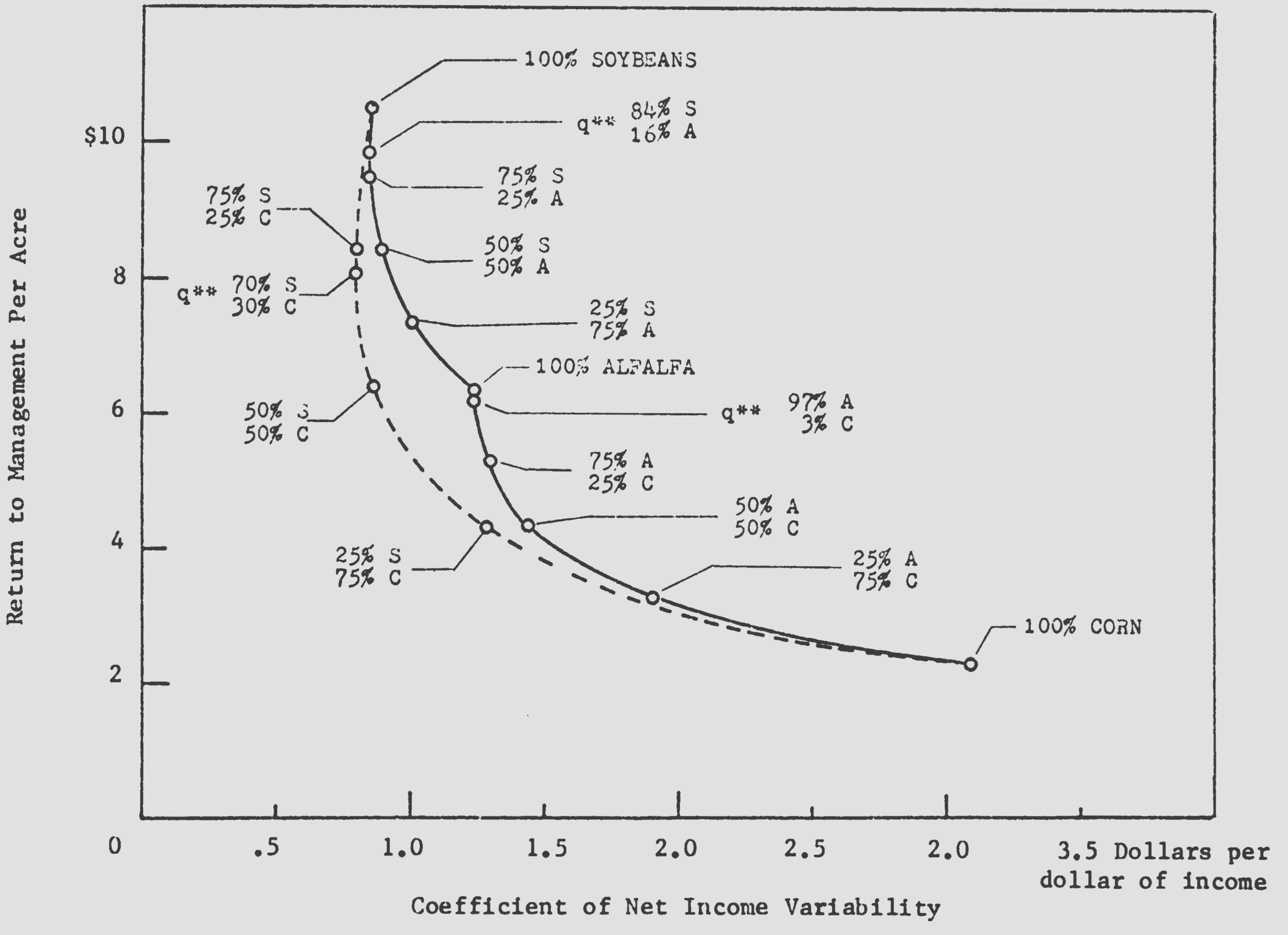

Figure 8. Income variability as measured by the coefficient of net income variation for various combinations of soybeans, alfalfa and corn.

advantage to diversification from a 100% soybean operation is far less. As the coefficient of net income variation is reduced from .8522 to .8458, expected income falls from $10.54 to $9.86.

Table 5 shows the expected income of the various cropping systems and the probability of loss. For example, soybeans with their expected income of $10.54 per acre can expect a loss once every 8.33 years as compared to corn which can expect a loss once every 2.70 years. Oats, on the other hand, with an expected annual loss of $16.53 can expect to produce a loss nearly 536 years to every year of profit. Growing milo and oats in a 44-56 ratio, which will minimize variability per acre, results in a guaranteed loss; that is the probability of producing a profit so small that it cannot be measured.

Other Crops

The crops of grain sorghum and oats will not be discussed with respect to net income variability for two reasons. First, both of these crops have an expected return which is negative; that is, you would expect to lose

Table 5. Expected income and probability of loss using different cropping techniques.

	Crop Ratios	Expected Incomes	Probability of Loss
Single Crops			
Soybeans	100-0	10.54	1:8.3
Alfalfa	100-0	6.33	1:4.7
Corn	100-0	2.28	1:2.7
Milo	100-0	- 4.26	4:1
Oats	100-0	-16.53	536:1
Minimizing Variability per Acre (q*)			
Corn-Soybeans	61-39	5.47	1:6.5
Soybeans-Alfalfa	34-66	7.77	1:6.7
Soybeans-Oats	17-83	-11.86	63.4:1
Soybeans-Milo	32-68	0.43	1:2.1
Corn-Alfalfa	59-41	3.93	1:3.8
Alfalfa-Oats	13-87	-13.50	119:1
Alfalfa-Milo	37-63	- 0.36	2.12:1
Corn-Milo	38-62	- 1.78	2.6:1
Corn-Oats	36-64	- 9.82	28.5:1
Oats-Milo	56-44	-11.11	Beyond Measure
Minimizing the Coefficient of Net Income Variation (q)**			
Corn-Soybeans	30-70	8.05	1:9.3
Soybeans-Alfalfa	84-16	9.86	1:8.4
Corn-Alfalfa	3-97	6.19	1:4.8

money growing these crops. Second is that, as these crops are included in a cropping program with the more profitable crops, the coefficient of net income variation increases rapidly as the expected income approaches zero. Thus, the coefficient of net income variation is minimized when 100% of the land is allocated to the profitable crop. For the interested reader, the effects of diversification with these crops is included in Appendix A.

WHICH ANALYSIS TO USE?

The above discussion of the two methods for minimizing income variability may have left you confused about which method to use. The "correct" one depends upon the situation in which the farm operator finds himself.

Minimizing Variability Per Acre

The reasons for minimizing the standard deviation of income per acre are different from seeking to minimize the coefficient of net income variation. The first is appropriate for the operator who has adequate profit per acre but is a risk averter or who is in a tight liquidity situation.

Those operators who are most likely in an undesirable liquidity position are new operators or those who for some reason have incurred a great deal of debt so they have a substantial fixed cash outflow relative to their expected cash inflow. Thus these operators could be forced out of business relatively easily due to a poor crop or low prices despite a relatively profitable operation over a period of several years. Consequently they may be willing to sacrifice some profitability in order to insure remaining in business until the liquidity situation can be improved.

Minimizing the Coefficient of Net Income Variation

The operators who would be concerned with minimizing the coefficient of net income variation rather than the standard deviation of income per acre would be those who are not troubled by low liquidity. In most cases, a lower coefficient of net income variation is due to higher expected net income rather than a lower standard deviation. This means that a combination of two crops which minimizes net income variation will likely have a higher expected net income and higher variability per acre than a combination which minimizes variability per acre, as in Table 6.

The corn and soybean combination in Table 6 readily reveals that if an operator had minimized the variability per acre during the time period the average income would have been $5.47 per acre with a range of $14.83 profit to $1.12 loss. Minimizing the coefficient of net income variation would give an average income of $8.06 per acre and a range of $17.79 profit to $2.07 loss. In either case 1968 was the only year with a loss.

In the corn-alfalfa operation, it is apparent that electing to minimize the coefficient of net income variation would be the preferred action. First, it raises the average income by more than one-third -- from $3.93 per acre to $6.21. An increase in the range accompanies the increase in average income. Using q*, the highest income was $11.32 and the lowest was a loss of $4.85. Minimizing the coefficient of net income variation changed the range to a high of $21.47 with a low of $1.18 loss. Another point that is illustrated here is that the number of years in which a loss occurred is reduced from 3 to 2. With a longer time series, there likely would be fewer years with an economic loss in the corn-soybean and soybean-alfalfa examples also.

The soybean-alfalfa combinations show basically the same phenomenon as

Table 6. Calculated income by year when using q* (minimizing the standard deviation per acre) and q** (minimizing the coefficient of net income variability) for corn, soybeans, and alfalfa.

		Proportion of land in 1st crop	YEAR 1964	1965	1966	1967	1968	1969	1970	1971	1975
Corn-Soybeans	q*	.61	3.11	8.45	14.83	0.30	-1.12	10.05	.62	8.69	8.76
Corn-Soybeans	q**	.30	6.92	6.54	16.57	1.28	-2.07	9.55	5.16	12.87	17.79
Corn-Alfalfa	q*	.59	0.35	10.97	10.94	-0.04	-0.34	11.32	-4.85	1.48	7.58
Corn-Alfalfa	q**	.03	3.12	11.13	8.61	1.19	-0.91	12.19	0.42	-1.18	21.47
Soybeans-Alfalfa	q*	.34	5.74	8.95	11.81	1.59	-0.95	11.16	3.64	4.88	23.68
Soybeans-Alfalfa	q**	.84	9.43	5.72	16.69	2.07	-2.66	9.57	8.12	14.00	25.83

do the corn-soybean and corn-alfalfa examples. Again, both the average income and the range or variability per acre are greater by minimizing the coefficient of net income variation; that is, choosing q** over q*. Also, as was the case with corn-soybeans, the year of greatest loss was made worse. This was not the case with alfalfa-corn, although it could be expected.

Consequently, a farmer who seeks to minimize the coefficient of net income variability needs a larger liquid reserve to insure continuation of operation. However the operator who is troubled with low profits, even if accompanied by low liquidity, may find minimizing the coefficient of net income variation the preferred action if it raises his expected income. This is especially true if the lower income obtained with minimizing variability per acre is not sufficient to keep the operation continuous.

The farmer operator who has satisfactory liquidity and can assume more risk may wish to move from the point where the coefficient of net income variation is minimized toward the crop which will increase expected income. How much additional risk he will be willing to undertake for an additional dollar of income will depend upon his security-income preference.

APPLICATIONS OF FINDINGS

Although this study can be used to help determine crop rotation without considering market or technological conditions, this practice is not recommended.

The expected profit from each crop should be estimated before crops are planted. After anticipated profits have been calculated and preliminary planning of crops done, then the plans should be reviewed in the light of the historical record of profitability and variability of the proposed crops. If the proposed crop plan differs significantly from what historically has been the "best" rotation, a more careful study of your plan may be in order. The following questions may help in evaluating.

Are the anticipated market projections significantly different from past market conditions? Are the anticipated yields significantly different or more certain than those of the past? (For example, if you are switching from dryland to irrigated

Ave.	High	Low	Standard Deviation	Coefficient of Variation
5.47	14.83	-1.12	5.3440	0.9778
8.06	17.79	-2.07	6.4843	0.8059
3.93	11.32	-4.85	6.1267	1.5578
6.21	21.47	-1.18	7.6050	1.2419
7.77	23.68	-0.95	7.4019	0.9529
9.87	25.83	-2.66	8.3396	0.8458

farming, crop yields may change significantly.)

If your answers to either of these questions is "yes," then deviations from the historically desirable crop combinations may be fully warranted. If anticipated market conditions or yields do not differ much from the 1964-1975 period, then a review of projected profits may be in order.

LIMITATIONS OF THE STUDY

The results of the study as presented in this report can be used only as a guide to selecting a combination of crops to reduce risk and/or increase net income. For an individual, the relative profitability of the various crops may differ from county averages due to managerial ability, topography, and soil conditions. Results cannot be taken from the report and used without an analysis of your particular farm's operation. However, because of the amount of the various crops raised and the difference in risk and income, the study does indicate that a number of farm operators need to reconsider their cropping practices.

The second limitation of the study is the short time period used. Generally speaking, the greater the number of observations, in this case the longer the time period, the better. However, a longer time period has two serious drawbacks. The first involves the techniques of collecting and reporting data, which change periodically, making the construction of reliable and consistent budgets for a longer period almost impossible.[5]

Another drawback to using a longer time period is that the inputs used by farmers are reported on a statewide basis rather than by counties. This lack of detail in reporting makes it impossible to construct reliable budgets for earlier years in which the level of technology was different. More detailed reporting of inputs and their prices could increase the accuracy of a study such as this one.[6] Variation in farming practices by counties cannot be accomodated in the study.

The third limitation is that the study is limited to looking at only two crops at a time. If more than two crops are investigated simultaneously the mathematics become considerably more complicated and the results difficult to present. However the technique used does give added insight to the problem of income variability and can be used as a guide to selection of profitable crops and their proportions.

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[5]For example, the prices paid for herbicides and insecticides were not reported prior to 1965. The price paid for diesel fuel was not reported until 1973, when fuel was reclassified from a motor vehicle cost to a cost of energy.

[6]It should be noted that the state of South Dakota has stopped reporting the production of crops by counties and the prices received by farmers as well as inputs used and prices paid on a statewide basis.

SUMMARY AND CONCLUSIONS

Crop diversification can be used in the east-southeastern counties to reduce income variability in dryland farming. Minimizing the standard deviation per acre is the most conservative approach a farm operator can take. While this approach maximizes the certainty of income per acre, it usually results in a lower income than do less conservative practices. For the operator with severe liquidity problems, this may be the appropriate policy.

Minimizing the coefficient of net income variability is less conservative, resulting in a higher expected income. Although the variability per dollar of income is minimized, the total variability per acre of land will be greater if this policy is pursued.

Due to the wide range in expected income per acre among the different crops, farm operators need to carefully choose the crops with which they wish to diversify. The profitability of each crop should be examined carefully before considering it as part of a rotation. During the period of history on which this study was based, oats and milo were consistent losers, while soybeans, alfalfa, and corn were the most profitable. Thus it appears that it may be profitable to eliminate oats and milo from most crop rotations in favor of the more profitable crops unless circumstances on a particular farm dictate otherwise. This is something each operator will have to examine for his own operation.

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APPENDIX

Table A-1. Income, variance, standard deviation, and coefficient of variation for corn and soybeans.

Crop Ratio	% Corn	Income	Variance	Standard Deviation	Coefficient of Variation
Corn: Soybeans					
Q*	61.0	5.47	28.5585	5.3440	0.9778
Q**	30.0	8.05	42.0459	6.4843	0.8059
0-100	0.0	10.54	80.6277	8.9793	0.8522
25-75	25.00	8.47	46.8673	6.8460	0.8080
50-50	50.00	6.41	30.3591	5.5099	0.8598
75-25	75.00	4.34	31.1030	5.5770	1.2838
100-0	100.00	2.38	49.0990	7.0071	3.0733

Table A-2. Income, variance, standard deviation, and coefficient of variation for corn and alfalfa.

Crop Ratio	% Corn	Income	Variance	Standard Deviation	Coefficient of Variation
Corn: Alfalfa					
Q*	59.0	3.93	37.5361	6.1267	1.5578
Q**	3.0	6.19	59.0593	7.6850	1.2419
0-100	0.0	6.33	61.7869	7.8605	1.2424
25-75	25.00	5.31	45.6203	6.7543	1.2708
50-50	50.00	4.30	18.1169	6.1739	1.4347
75-25	75.00	3.29	39.2764	6.2671	1.9039
100-0	100.00	2.28	49.0990	7.0071	3.0733

Table A-3. Income, variance, standard deviation, and coefficient of variation for corn and oats.

Crop Ratio	% Corn	Income	Variance	Standard Deviation	Coefficient of Variation
Corn: Oats					
Q*	36.0	-9.82	25.2328	5.0232	-0.5116
Q**	100.00	2.28	49.0990	7.0071	3.0733
0-100	0.0	-16.53	32.5843	5.7083	-0.3452
25-75	25.00	-11.83	25.8925	5.0885	-0.4301
50-50	50.00	-7.13	26.4143	5.1395	-0.7211
75-25	75.00	-2.42	34.1498	5.8438	-2.4112
100-0	100.00	2.28	49.0990	7.0071	3.0733

Table A-4. Income, variance, standard deviation, and coefficient of variation for corn and milo.

Crop Ratio	% Corn	Income	Variance	Standard Deviation	Coefficient of Variation
Corn: Milo					
Q*	38.0	-1.78	33.3331	5.7735	-3.2375
Q**	100.00	2.28	49.0990	7.0071	3.0733
0-100	0.0	-4.26	39.1694	6.2585	-1.4707
25-75	25.00	-2.62	34.0042	5.8313	-2.2243
50-50	50.00	-0.99	33.9375	5.8256	-5.8977
75-25	75.00	0.65	38.9690	6.2425	9.6617
100-0	100.00	2.28	49.0990	7.0071	3.0733

Table A-5. Income, variance, standard deviation, and coefficient of variation for soybeans and alfalfa.

Crop Ratio	% Soybeans	Income	Variance	Standard Deviation	Coefficient of Variation
Soybeans: Alfalfa					
Q*	34.0	7.77	54.7878	7.4019	0.9529
Q**	84.00	9.86	69.5487	8.3396	0.8458
0-100	0.0	6.33	61.7869	7.8605	1.2424
25-75	25.00	7.38	55.2967	7.4362	1.0077
50-50	50.00	8.43	56.2734	7.5016	0.8897
75-25	75.00	9.48	64.7171	8.0447	0.8482
100-0	100.00	10.54	80.6277	8.9793	0.8522

Table A-6. Income, variance, standard deviation, and coefficient of variation for soybeans and oats.

Crop Ratio	% Soybeans	Income	Variance	Standard Deviation	Coefficient of Variation
Soybeans: Oats					
Q*	17.0	-11.86	30.3969	5.5133	-0.4648
Q**	100.00	10.54	80.6277	8.9793	0.8522
0-100	0.0	-16.53	32.5843	5.7083	-0.3452
25-75	25.00	-9.77	30.8360	5.5530	-0.5686
50-50	50.00	-3.00	38.2605	6.1855	-2.0626
75-25	75.00	3.77	54.8577	7.4066	1.9652
100-0	100.00	10.54	80.6277	8.9793	0.8522

Table A-7. Income, variance, standard deviation, and coefficient of variation for soybeans and milo.

Crop Ratio	% Soybeans	Income	Variance	Standard Deviation	Coefficient of Variation
Soybeans: Milo					
Q*	32.0	0.43	27.8499	5.2773	12.3717
Q**	100.0	10.54	80.6277	8.9793	0.8522
0-100	0.0	-4.26	39.1694	6.2585	-1.4707
25-75	25.00	-0.56	28.3500	5.3245	-9.5506
50-50	50.00	3.14	31.6532	5.6261	1.7914
75-25	75.00	6.84	49.0791	7.0056	1.0244
100-0	100.00	10.54	80.6277	8.9793	0.8522

Table A-8. Income, variance, standard deviation, and coefficient of variation for alfalfa and oats.

Crop Ratio	% Alfalfa	Income	Variance	Standard Deviation	Coefficient of Variation
Alfalfa: Oats					
Q*	13.0	-13.50	31.8846	5.6466	-0.4182
Q**	100.00	6.33	61.7869	7.8605	1.2424
0-100	0.0	-16.53	32.5843	5.7083	-0.3452
25-75	25.00	-10.82	32.4318	5.6949	-0.5264
50-50	50.00	-5.10	37.2481	6.1031	-1.1958
75-25	75.00	0.61	47.0331	6.8581	11.2172
100-0	100.00	6.33	61.7869	7.8605	1.2424

Table A-9. Income, variance, standard deviation, and coefficient of variation for alfalfa and milo.

Crop Ratio	% Alfalfa	Income	Variance	Standard Deviation	Coefficient of Variation
Alfalfa: Milo					
Q*	37.0	-0.36	27.4814	5.2423	-14.7544
Q**	100.0	6.33	61.7869	7.8605	1.2424
0-100	0.0	-4.26	39.1694	6.2585	-1.4707
25-75	25.00	-1.61	28.6909	5.3564	-3.3270
50-50	50.00	1.04	28.9677	5.3822	5.1974
75-25	75.00	3.68	39.9997	6.3245	1.7181
100-0	100.00	6.33	61.7869	7.8605	1.2424

Table A-10. Income, variance, standard deviation, and coefficient of variation for oats and milo.

Crop Ratio	% Oats	Income	Variance	Standard Deviation	Coefficient of Variation
Oats: Milo					
Q*	56.0	-11.11	21.6130	4.6490	-0.4183
Q**	98.0	-16.32	31.7443	5.6342	-0.3452
0-100	0.0	-4.26	39.1694	6.2585	-1.4707
25-75	25.00	-7.33	26.9697	5.1932	-0.7089
50-50	50.00	-10.39	21.8056	4.6696	-0.4492
75-25	75.00	-13.46	24.6771	4.8659	-0.3614
100-0	100.00	-16.53	32.5843	5.7083	-0.3452

Table B-1. 1975 cost budgets for the five crops studied.

	Corn	Soybeans	Alfalfa	Milo	Oats
Seed	$ 6.78	$ 9.98	$ 4.03	$ 1.46	$ 6.98
Insecticide	4.50	1.75	3.25	3.50	1.00
Herbicide	3.20	4.70	-0-	3.90	1.20
Machine repair	3.55	3.35	8.15	3.30	2.65
Fuel, oil, grease	5.51	4.35	4.10	4.60	3.40
Overhead	3.00	3.00	3.00	3.00	3.00
Subtotal	26.54	27.13	22.53	19.76	18.14
Interest rate	8.8%	8.8%	8.8%	8.8%	8.8%
Interest cost	1.17	.99	.66	.87	.67
Drying cost	5.46	---	---	5.08	-0-
Labor	8.75	6.25	16.25	6.00	5.00
Total	41.92	34.37	39.44	31.71	23.81
Fertilizer	19.48	5.51	11.33	19.48	14.26
Interest	.86	.20	.75	.86	.52
Total v.c.	62.26	5.71	51.52	52.05	38.59
Machine depreciation	8.50	8.20	6.00	8.20	7.00
Machine interest	4.13	3.96	2.92	3.96	3.41
Total machine & v.c.	74.89	52.96	60.44	64.21	49.00
Land charge	48.00	48.00	48.00	48.00	48.00
Total cost of prod.	$122.89	$100.96	$108.44	$112.21	$97.00

Return to management (or profits) were calculated by subtracting total cost of production from current market value of the crop produced in each year.