RISK ANALYSIS OF CROPPING SYSTEMS USING EXPERIMENTAL CROPPING SYSTEM-FERTILIZER DATA[1]

by

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Background

Agricultural risk analysis has had a rich theoretical and modeling history. However, data limitations have often not permitted the degree of practical application of risk analysis that many desire. In cropping analysis, long-term yield histories by cropping system (specific rotations or continuous cropping) at the farm level have generally not been available. In place of these, aggregate yield data for larger units (often county) are frequently used with the analysis commonly developed on a general crop basis rather than on a specific cropping system basis. When risk analyses are completed without crop sequence specificity the risk-return results lack direction regarding how and if crops are to be sequenced. Cropping system interactions important to the analysis can fail to emerge in such cases. One interaction is the yield benefit of growing one crop after another.

In addition, cost benefits involving reduced operating inputs can arise for some cropping sequences. For example, with some crop rotations reduced fertilizer is required compared to growing each crop of the rotation in a continuous sequence. Similarly, sequencing crops can reduced the need for other inputs such as insecticides.

Last, with some crop rotations, there may arise yield stability aspects not observant using county or even farm data on a general crop basis. It is generally thought that crop rotations provide yield stability compared to an equal degree of diversification achieved by growing two or more crops continuously. Ignoring these yield, cost, and stability aspects accruing to some crop sequences may bias the results of risk modeling.

In this study, experimental yields were available to permit risk analysis of cropping systems. Further, the cropping system data included alternative fertilizer levels such that this factor could also be included in the analysis. A number of risk models were examined to allow simultaneous comparison of risk results for various risk criteria

Objective

The objective of this study was to analyze cropping risk using cropping system yield data (including alternative fertilizer levels) for both continuous crops (corn, grain sorghum, and soybeans) and two two-crop rotations of these crops. A MOTAD framework was developed and used to compare selected Target-MOTAD solutions, selected Safety-First solutions, and undominated (first degree stochastic dominance) cropping system-fertilizer alternatives. Thus, a second objective was to analyze risk from various risk models in the same risk framework.

Procedure

Risk models (MOTAD, Target-MOTAD, and Safety First (exact) were constructed using experimental yield data for 1984-95 for an eastern Nebraska location (Varvel). A MOTAD framework was used to compare the outcomes of each model. Also, first degree stochastic dominance was used to select undominated solutions from nine continuous cropping alternatives and 18 rotation alternatives.

The yield data involved the following crops: 1) grain sorghum (G), soybeans (B), and corn (C) each grown behind the same crop and 2) corn following soybeans (BC), grain sorghum following soybeans (BG), soybeans following corn (CB) and soybeans following grain sorghum (GB). For each crop three nitrogen fertilizer levels were applied. For corn and grain sorghum the levels were zero, 80, and 160 lb. of nitrogen per acre. For soybeans the three levels were zero, 30, and 60 lb. per acre.

These yield data allowed 5 basic crop sequences to be considered including continuous grain sorghum, soybeans, and corn as well as corn-soybeans and grain sorghum-soybeans. Each continuous alternative involved three fertilizer levels (total of 9). Each of the two rotations involved 9 two-crop fertilizer combinations (total of 18). For example, corn-soybeans with corn fertilized at level 1 and soybeans fertilized at level 1, corn-soybeans with corn fertilized at level 2 and soybeans fertilized at level 1, etc.

Using Nebraska average prices of each crop for the 11 years as well as estimated cost of production for each crop (depending on sequence) net returns were estimated for each of the 27 systems for each of the 11 periods.

A MOTAD frontier was first estimated for selected points. These involved the maximum net return solution as well as the point at which land became slack and three points between.

For two points on the MOTAD frontier, target-MOTAD solutions were found for arbitrarily selected targets. Also three exact Safety-First solutions were found involving three different probabilities (1 of 11, 2 of 11, and 3 of 11) of falling below an arbitrary annual disaster level.

Last, for each of the 15 undominated stochastic dominance crop sequences, each was "driven" through the MOTAD framework. This was also done for the target-MOTAD and safety-first solutions allowing all solutions to be compared on a common basis..

Data

Average yields by cropping system are presented in Table 1 (Varvel). The Nebraska prices used in the analysis were secured from Wellman.

Operating costs for corn following corn and soybeans were assumed to be $117.50 and $103.90 respectively. For grain sorghum following grain sorghum, and soybeans, costs were assumed to be $78.60 per acre for each. Costs for soybeans following soybeans, corn, and grain sorghum were assumed to be $108.42, $88.42, and $88.42 per acre respectively. These costs were assembled from Selley et al. and Duffy. Nitrogen was assumed to cost $0.20 per lb. The cost of nitrogen is not included in the above described operating costs.

In Table 2 net returns by cropping system for each year are presented. Net returns are returns to land, labor, and machine ownership. Machine ownership costs as well as labor could be assessed by cropping system, however only operating cost differences were included in this analysis.

Models

Risk models involve a fixed enterprise combination across time. Diversification has long been of interest to agricultural analysts. Hazell developed MOTAD as a Linear Programming methodology to analyze risk. In 1982 the concept of the use of targets as opposed to the mean was presented (Held, et al.). In 1983 Tauer and in 1984 Watts, et al. published the target concept as Target-MOTAD. Various forms of Safety-First concepts have been developed. Here, an "exact" Safety-First model is used (Watts, et al. 1989) in which Integer Programming is used to allow exact probabilities of failure to meet the selected disaster level is employed.

Results

The results are presented in Table 3. They are also graphed in Figure 1. While a MOTAD frontier is used as a common measure here it should not be inferred that a mean deviation framework is necessarily the best representation of risk. The results are discussed by sub-analysis.

MOTAD.

The maximum net return solution involves the rotation of corn and soybeans with corn fertilized at 80 lb./acre and no nitrogen applied to soybeans. The return is $118.36 per year. At the other extreme is the point just before land enters slack which involves a net return of $83.64 per acre ($1,840). Negative deviations for this solution are roughly 47 percent of that maximum return solution. The minimum deviation solution involves nearly 1 acre of the corn-soybean rotation (corn and soybeans are both fertilized at the zero level) but also includes .63 acres of continuous grain sorghum and .41 acres of continuous soybeans (also both fertilized at the zero level).

The three intermediate solutions involve a grain sorghum-soybean rotation with continuous soybeans and later continuous grain sorghum dropping out as returns increase. The only cropping system not entering any solution on the MOTAD frontier is continuous corn. Considerable variation in fertilizer application levels are observed from the results suggesting that fertilizer choices are important to risk analysis.

Target-MOTAD.

The $2,250 net return Target-MOTAD solution with the $2,000 target is similar in organization to the $2,250 MOTAD solution. This can also be observed in Figure 1 in its close proximity to the MOTAD frontier. At a $1,750 target for the $2,250 net return, continuous corn and continuous grain sorghum occupy the solution along with the corn-soybean rotation. This suggests continuous corn and continuous grain sorghum are useful when risk is viewed as falling below a low target. Continuous cropping is generally hypothesized to be more risky compared to rotational cropping. However, for both the MOTAD and Target-MOTAD analysis, continuous cropping frequently enters solutions. At the minimum return level $1,840) at the 1590 target the solution is similar to the $1,840 MOTAD solution.

Safety-First.

An attempt was made to roughly select the highest disaster level achievable at each of three probability levels. Hence, lower probability solutions involve less risk and allow for higher returns. However, the choice of the disaster level also strongly influences the solution. Data "holes" in terms of yield and price distributions also influence results and make comparisons difficult among Safety-First solutions.

The first, Safety-First solution which involves the restriction that only in one year of 11 are net returns to fall below a disaster level ($125) is a high risk solution in terms of overall MOTAD risk. From a MOTAD perspective it is also very inefficient as seen in Figure 1. The other two Safety-First solutions are close to the MOTAD frontier involving both higher and lower returns than the first solution.

Undominated Systems.

The results for the undominated cropping systems are also presented in Table 3 and Figure 1. Because of obvious inefficiency, systems 14 and 15 are omitted from Figure 1. It can be observed from Figure 1 that all systems are markedly inefficient except the maximum return rotation which is the maximum return MOTAD point (corn-soybeans). It is obvious that different fertilization levels not only affect returns but risk as well.

Conclusions

In the study area farmers have generally practiced rotation agriculture in the past. Commonly, roughly one-half of cropland has been in feedgrains and one-half in soybeans. It is unclear to what degree past commodity programs have affected feedgrain acreage through the program base restriction. With this removed in the current program an important issue is to what degree cropland patterns will change.

The results of this study suggest that using a traditional risk-return model (MOTAD), feedgrain and soybean acreage tends to be roughly equal but slightly more oriented to feedgrains. Target-MOTAD results suggest considerable higher levels of feedgrains relative to soybeans. Because of limited observations the results for safety-first models relative to feedgrain-soybean proportions cannot be concluded here.

The benefits of using experimental data to study risk appears strong. Compared to "general" yield data by crop, cropping system analysis is enhanced by this process.

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Table 1. Average Yields for Seven Cropping Sequences at Three Fertilization Levels 1984-94 (Varvel).

Sequence	Yield (bu./ac.)
C1	67
C2	116
C3	131
G1	54
G2	101
G3	109
B1	36
B2	35
B3	35
BC1	106
BC2	138
BC3	137
CB1	39
CB2	34
CB3	37
GB1	38
GB2	38
GB3	40
BG1	94
BG2	108
BG3	109

Table 2. Estimated Net Returns to Land, Labor, Machine Ownership, and Management by Cropping System for Each Year of the Study ($/ac.).

		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Ave
C	1	81.81	-13.05	-17.19	9.95	-8.10	15.01	11.24	21.96	41.02	2.66	-76.74	6.23
	2	159.46	44.15	45.45	54.34	102.71	74.35	106.38	136.74	136.11	102.03	-54.53	92.39
	3	181.03	92.71	28.66	83.15	88.21	65.86	81.08	153.00	169.45	156.66	3.59	100.31
BC	1	124.03	79.48	86.10	120.08	44.41	48.92	111.77	109.07	157.76	137.24	30.01	95.35
	2	237.38	92.75	143.29	134.16	4.71	76.35	165.16	206.90	220.63	198.26	53.26	139.35
	3	202.08	81.68	104.01	84.18	47.00	-100.78	130.89	192.63	207.70	186.08	36.08	106.50
G	1	56.44	10.86	1.98	88.44	-30.76	55.59	13.44	-14.58	-41.92	-5.52	-49.89	7.64
	2	137.50	55.92	17.58	125.80	67.64	126.92	165.00	39.26	7.58	57.65	-38.14	69.34
	3	117.28	55.54	6.32	112.12	89.08	119.44	198.56	42.66	15.16	41.65	39.33	76.10
BG	1	113.41	66.24	39.90	127.88	71.16	115.23	143.24	59.14	65.50	75.68	4.34	80.16
	2	124.84	67.28	46.02	121.16	84.07	120.32	177.74	68.36	68.63	63.54	14.82	86.98
	3	100.40	45.60	-1.58	123.72	70.36	108.79	153.72	9.68	67.56	76.16	55.28	73.61
B	1	53.81	101.66	113.20	73.84	-23.31	47.26	28.94	94.34	125.51	84.83	22.21	65.66
	2	38.27	79.92	103.88	67.77	-28.82	38.98	28.91	90.76	97.93	93.21	16.96	57.07
	3	3.76	72.92	88.27	59.92	-28.96	34.26	39.99	85.63	115.94	82.50	-5.86	49.85
CB	1	48.18	142.76	133.61	86.18	11.33	102.24	110.16	103.21	146.70	151.31	35.14	97.35
	2	30.90	127.52	98.74	29.25	-9.36	65.77	69.47	94.17	112.71	121.32	40.71	71.02
	3	45.43	129.68	100.51	64.52	-7.99	82.33	97.84	71.18	102.35	124.42	44.83	77.75
GB	1	76.78	132.57	131.31	117.94	13.80	84.25	94.16	76.38	147.94	133.89	11.58	92.78
	2	47.18	113.04	120.20	126.68	2.42	89.39	66.68	75.53	148.16	153.74	18.08	87.37
	3	36.46	120.57	124.42	135.42	-3.58	100.10	92.90	79.83	154.60	142.57	43.33	93.33

Table 3. Crop Organization, Estimated Net Returns, and Negative MOTAD Deviations for Selected MOTAD Solutions, Selected Target-MOTAD Solutions, Selected Exact Safety-First Solutions, and 15 Undominated Stochastic Dominance Cropping Systems.

Group	Crop Organization[1]	Net Returns[2] $	Negative Deviations[3]
MOTAD	.48BC1, .63G1, .41B1, .48CB1	1840	207.6
	.6BC1, .39G3, .2BG2, .6CB1, .2GB3	2000	233.4
	.49BC2, .22G3, .4BG2, .49CB1, .4GB3	2250	278.3
	.84BC2, .16BG2, .84CB1, .16GB3	2500	386.6
	1BC2, 1CB1	2604	444.5
Target-MOTAD			
TM1	.59BC2, .66G3, .08BG2, .59CB1, .08GB3	2250[4] (2000)	290.2
TM2	.32C3, .53BC2, .62G3,. .53CB1	2250 (1750)	320.4
TM3	.31BC3, 1.26G3, .11B1, .31CB1	1840 (1590)	263.3
Exact Safety First[5]			
SF1 1/11, 125	1.1C3, .45BC2, .45CB1	2334	468.94
SF2 2/11, 205	.38BC2, .61BG2, .38CB1, .61GB3	2209	276.4
SF3 3/11, 225	.89BC2, .11BG1, .89CB1, .11GB3	2528	406.1
Undominated Systems			
1	1CB1, 1BC2	2604	444.5
2	1CB3, 1BC2	2388	416.1
3	1CB2, 1BC2	2314	446.5
4	2C3	2207	517.7

Group	Crop Organization[1]	Net Returns[2] $	Negative Deviations[3]
5	1CB1, 1BC1	2120	326.5
6	1GB3, 1BG2	1983	282.9
7	1GB1, 1BG2	1977	272.6
8	1GB2, 1BG2	1918	270.2
9	1GB3, 1BG1	1908	298.9
10	1CB3, 1BC1	1904	280.4
11	1GB3, 1BG3	1836	320.8
12	1CB2, 1BC1	1830	307.1
13	1GB1, 1BG3	1830	298.7
14	1GB2, 1BG3	1771	309.6
15	2G3	1674	511.8

[1] Beginning numbers refer to acres. BC refers to corn following soybeans, CB is soybeans following corn, BG is grain sorghum following soybeans, and GB is soybeans following grain sorghum. G, B, and C refer to grain sorghum, soybeans, and corn grown continuously. Ending numbers refer to fertilizer level as explained in text.
[2] For two acres and 11 periods.
[3] For two acres, 11 periods, and expressed on a MOTAD basis.
[4] Number in parentheses are target levels.
[5] Periods of 11 that net returns are allowed to fall below a two acre disaster level (for example, $125).

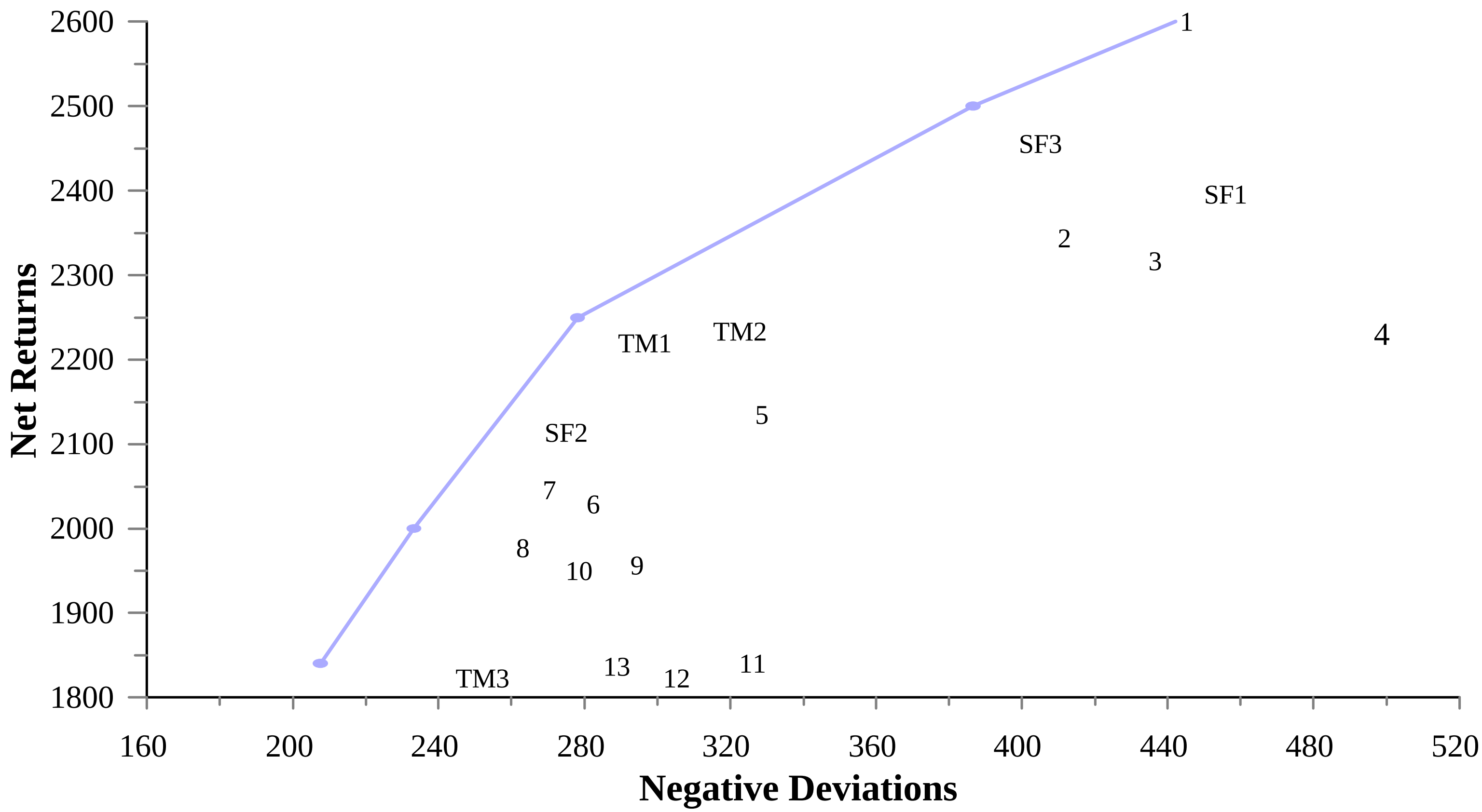

Figure 1 **Estimated Net Returns and Negative MOTAD Deviations for MOTAD, Target-MOTAD, Safety-First and Undominated Cropping Systems(2 acres, 11 periods).**