Crop Flexibility in Dryland Corn and Soybeans Using Predicted Yields and Prices

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Presented at Western Agricultural Economics Association 1997 Annual Meeting
July 13-16, 1997
Reno/Sparks, Nevada

July 1997

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Abstract

Using experimental data on corn and soybean yields in eastern Nebraska, a yield prediction model was constructed. In concert with the use of futures prices, a programming model was constructed to select optimum short run cropping systems. The performance of the model was compared to models using actual outcomes. The results demonstrate significant advantages over conventional rotation cropping.

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The removal of commodity program base planting restrictions has led many to conclude that cropping economics will be increasingly risky. Flexibility has long been suggested as one economic strategy to cope with variable economic conditions. Traditionally flexibility in agriculture has been in reference to a flexible capital investment which allows relatively rapid varied output adjustments in response to changing economic conditions.

In this study the flexibility context is changing cropping systems in response to variable yields and prices. The setting is dryland cropping in eastern Nebraska. In particular, two crops, corn and soybeans, are widely grown in rotation (one-half of each per year). However, each crop can also be grown continuously which allows a producer to grow only one crop in a given year. If economic conditions are such that the benefits to that crop are great enough the producer may be inclined to depart from the rotation for a year.

Several reasons may limit the advantages of departing from the rotation. One is the large costs of maintaining a larger machine-labor set necessary for extreme year to year crop adjustments compared to a stable cropping system. That aspect is not considered here in that only operating costs of each crop are examined. Second is the issue of yield interactions between corn and soybeans when grown in rotation. Departing from the rotation involves growing one crop as a continuous crop on one half the cropland in the year of decision. However, assuming that both crops will be again grown the following year, a second year of a continuously grown crop (again on one-half of the acreage) must be grown. Also, each continuously grown system can involve significantly increased cost of fertilizer, herbicide, and insecticide compared to that crop grown in rotation. Further, to effectively change cropping systems when benefits outweigh cost presumes that the benefits can be reasonably well

predicted. If prediction is inaccurate, the performance of a flexible system could be significantly less than a "naive" rotation system as routinely followed.

Objective

The objective of this analysis is to examine both in the case of perfect and imperfect knowledge, the economies of flexible cropping. The specific context is eastern Nebraska dryland corn and soybean production where corn and soybeans are traditionally grown in rotation.

General Procedure

Eleven years of data from experimental trials of four cropping systems each fertilized at three nitrogen levels (Varvel) were analyzed. The systems were continuous corn (CC), continuous soybeans (BB), corn on previously grown soybeans (BC), and soybeans on previously grown corn (CB). A model of predicted yields for each system was developed utilizing only information previous to the predicted yield year. Corn and soybean futures prices (adjusted for basis) were used as predicted crop prices. Together these two factors allowed a model to be constructed in which it would be possible to change an existing cropping system in the short run under certain price-yield conditions.

One analysis examined optimal decisions with perfect forward knowledge of prices and yields (both short-term and full period optimization). This provides a context of the potential for flexibility were the future known perfectly. A second analysis examined short-run optimization based on predicted yields and prices.

The perfect knowledge full period optimization model used multi period linear programming. A short-run (year by year) perfect knowledge model employed a two-year linear programming model. This model included a constraint that the second year include equal proportions of corn and soybeans. The projection analysis obviously could not attempt a full

period analysis. It employed a two-year model using predicted prices and yields for the first year. Average prices and yields were used for the second year. All analyses assumed that previous to the 11 year period corn and soybeans were grown in equal proportions.

Yield and Price Projections

For the twelve cropping systems a precipitation index was used to estimate yields one year in advance. The performance of this model compared to actual yield is demonstrated in Figures 1 and 2 for corn and soybeans respectively. Only the medium fertilizer level results are shown.

The standardized precipitation index (SPI) is a computerized drought classification index developed by McKee et al. It can be computed for any given period as the difference of precipitation from the long-term (>30 years) mean divided by the standard deviation and normalized using the gamma function. Standardized precipitation index values greater than zero indicate wet conditions and values less than zero signify drought. An SPI of -2 or less implies an extreme drought condition. The preseason 8-month March SPI was used to predict the subsequent season's crop yield performance. The 8-month March SPI included residual moisture from crop maturity from the previous September to the April projection point. The role of preseason April temperatures was examined, but its inclusion in the model contributed insignificantly to the prediction of corn and soybean yields. A March SPI is justified by the fact that farmers in eastern Nebraska make major farm management decisions prior to planting time in April/May. The importance of preseason and growing season moisture for crop production is discussed by Wilhite and Glantz. Agronomically, adequate preseason moisture favors microbial activity, mineralization, and extensive development of roots of young plants. Deep root development enables the plants to exploit and survive on subsoil moisture should there be insufficient moisture during the growing season. Summer months (June to August) in eastern

Nebraska usually experience moisture deficit, thus, it may be safe to associate preseason moisture status with overall crop productivity of the season under nonirrigated farming systems.

Space limitations do not permit the presentation of the reduction in yield variability across all fertilizer levels from using predicted yields as opposed to mean yields (Figures 1 and 2). The greatest reductions are in continuous corn (60-70% using the predicted rather than the mean), corn after soybeans (roughly 70%), continuous soybeans (roughly 75%), and soybeans following corn (85-90%).

Projected and actual (Wellman) prices of corn and soybeans are presented in Figure 3. For projected prices of corn in December, a March futures price is used with a basis of $.22 per bu. (Lutgen). For projected soybean prices in November, a March futures price is also used with a $.44 per bu. basis. Standard deviations of actual prices for corn and soybeans using the means were $.405 and $.826 respectively for the 11 year period (1985-95). Futures prices when used as opposed to the mean reduced the standard deviation for corn prices to $.233 a larger relative reduction compared to soybeans ($.70).

Alternative Models

The models analyzed here can be divided into perfect and predicted as well as short and long-run.

Perfect Knowledge - Long Run

Here actual prices and yields are used in a 11-year multi period programming model.

1. Unrestricted. This allows the optional system to be selected for each year "looking forward" to all subsequent events.
2. Diversified. Here an annual requirement of equal proportions of corn and soybeans are imposed.

3. Constant Rotation. A more restrictive setting than (2) in which rotations are required and further, the rotations selected must be identical all eleven years.
4. Constant Rotation - Constant Fertilizer. A more restrictive setting than (3) where the fertilizer decision is required to be the same each year. This alternative would likely be selected as the decision to employ each year in a "naive" profit maximizing sense.

Perfect Knowledge - Short Run

5. The optimum plan for year t is determined by a two year model where the actual outcomes are included in the two years. A requirement is included so that the second year involves both corn and soybeans equally. This is done to keep the model from "flipping" from corn to soybeans in years following t should the model selects all of one crop in year t. Also, this restriction requires the model to consider costs of returning to a rotation in year t+1 should it depart in year t.

Projected Prices and Yields

6. A two-year short run model similar to (5) was constructed using projected prices and yields in year t but average actual prices and yields in year t+1. Again a requirement was included so that both corn and soybeans entered year t+1.

The 11 annual results for models 5 and 6 were both placed in the same model space as models 1-4 allowing direct performance comparison of models. For both models 5 and 6 whenever the short run model dictated all of one crop in year t and the subsequent adjustment in t+1, the second year adjustment was entered into the test. Otherwise, each of the 11 annual decisions was placed in the comparison test.

Model Assumptions

The programming model either in full period or short-run form is made up of 12 crop

alternatives. These are corn following corn, soybeans following soybeans, corn following soybeans, and soybeans following corn each fertilized at three levels. For corn the levels of nitrogen are zero, 80, and 160 lb./ac. For soybeans the levels are zero, 30, and 60 lb./ac.

Costs for seed, fuel, herbicides, insecticides, and other operating costs totaled $117.50 per acre for corn following corn, $108.42 per acre for soybeans following soybeans, $88.42 per acre for soybeans following corn, and $103.90 per acre for corn following soybeans. Nitrogen was assumed to cost $.20 per lb./ac. These were assembled from Selley et al. and Duffy.

It was assumed that adequate machinery and labor was available for any cropping system selected. A complete long-run analysis of the problem would include costs by system for these factors. In the short run there may be cases where the assumption of adequate machinery and labor is valid.

Results

The outcomes to all models is shown in Table 1. Model 1 using actual conditions with no restrictions has an 11 year objective function of $1505. The objective function represents returns to labor, machinery ownership, and land. Each year's crop organization must be logically linked to the previous year. It can be seen that in Model 1 considerable "forward looking" occurs as well as rotation "flipping" (years 6 and 7). For models 2 (diversified), 3 (a constant rotation imposed), and 4 (constant rotation and fertilizer choice imposed) objective functions are considerably reduced.

While the short run models 5 (actual outcomes) and 6 (predicted outcomes) are expected to have objective functions less than model 1, their performance is not greatly reduced and better than models 2, 3, and 4. Further, there is little difference between models 1 and 5 suggesting that under full knowledge the short-run model (5) performs nearly as well as

the long-run model (1). Model 6, the focus of this study, performs very well and better than models 2 and 3 which are long-run models under perfect knowledge but restricted to diversification and rotations respectively. It can be seen that model 6 performs much better than the fixed system 4 (one rotation fertilized at one rate). There are occasional differences between models 5 and 6. In years 4 and 5, model 5 chose all corn while model 6 diversified. In year 8 the opposite occurred.

In model 6 for two years (1 and 8), the entire acreage is devoted to corn. As discussed earlier the implications of this to machine-labor sets are ignored here. For those situations where the machine ownership and labor costs are significantly higher than for a traditional rotation (say model 4), these increased costs must be compared to the benefits achieved in model 6.

In summary, the high and surprising performance of model 6 suggests that prior information can be very successfully incorporated into management decisions for this setting. The projection of yields for other areas and experimental yield data may perform better or less well. However, for the setting of this study, using projected prices and yields allows considerable improvement over a traditional rotational strategy.

Table 1. Optimum Cropping System Proportions and Fertilizer Level for Each of the Six Study Models.[1]

	Model					
	1	2	3	4	5	6
10-Year Returns	$1505.04	$1338.35	$1327.81	$1301.82	$1480.08	$1410.54
Period						
1	.5 CC3 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CC3 .5 BC2	.5 CC3 .5 BC2
2	1 CB12	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	1 CB1	.5 CB1 .5 BC2
3	1 BB13	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 BB1 .5 BC2	.5 CB1 .5 BC2
4	1 BC24	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CC3 .5 BC2	.5 CB1 .5 BC2
5	1 CC2	.5 CB2 .5 BB1	.5 CB1 .5 BC3	.5 CB1 .5 BC2	1 CC2	.5 CB1 .5 BC3
6	1 CB1	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 CC2	.5 CB1 .5 BC2
7	1 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2
8	.5 CC3 .5 CB1	.5 CB1 .5 CB2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CC3 .5 BC2
9	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2
10	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2	.5 CB1 .5 BC2
11	.5 CB3 .5 BC2	.5 CB3 .5 BC2	.5 CB3 .5 BC2	.5 CB1 .5 BC2	.5 CB3 .5 BC2	.5 CB3 .5 BC3

[1] The first number represents either one half or one acre. Crop CC represents corn following corn, BB refers to soybeans following soybeans, CB is soybeans following corn, and BC is corn following soybeans. The last number refers to fertilizer level as explained in the text.

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