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STAFF PAPER

USE OF A CROP SIMULATION MODEL TO PROVIDE LONG-TERM DATA FOR ECONOMIC ANALYSIS: THE CASE OF EARLY MATURING SOYBEANS

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USE OF A CROP SIMULATION MODEL TO PROVIDE LONG-TERM DATA FOR ECONOMIC ANALYSIS: THE CASE OF EARLY MATURING SOYBEANS

Abstract

A target MOTAD model is used to investigate incorporation of early maturing soybeans by a crop farm in southeastern Kansas. Weather (WGEN) and crop simulation (SOYGRO) models are used to generate a long-term series of soybean yields. Results indicate that early maturing soybeans offer a risk-reducing diversification strategy.

USE OF A CROP SIMULATION MODEL TO PROVIDE LONG-TERM DATA FOR ECONOMIC ANALYSIS: THE CASE OF EARLY MATURING SOYBEANS

This study investigates the economic consequences of incorporation of early maturing soybeans (EMS) by a crop farm in southeastern Kansas. The most common soybean cultivars grown in southeastern Kansas are from maturity groups III through V, which are normally planted in June and harvested in October. In this paper, these are referred to as traditional soybeans (TS). The most promising EMS in southeastern Kansas are members of maturity group I. These are planted in late April and harvested in late July or August, taking advantage of spring rainfall and avoiding late summer droughts. Moreover, soybean prices are usually higher in July and August than in October. For example, Agricultural Prices show that the 1970-1988 average monthly prices per bushel for soybeans in Kansas were July-$5.77, August-$5.88, and October-$5.51. Thus, EMS offer a possible diversification strategy from traditional soybeans. Because the timing of planting and harvesting of EMS differs from that of TS, incorporation of EMS by a representative crop farm has implications for income, risk, labor usage, machinery size, field work hours, cash flow, and management time.

In response to farmer interest, an investigation of the agronomic potential of early-maturing soybeans at the Southeast Kansas Branch Experiment Station was initiated in 1986 (Granade 1987). Because of favorable results, the research was redesigned for a 5-year period starting in 1987, to further investigate the potential of EMS versus TS cultivars (Granade 1988, 1989). Thus, when this study was initiated, only 2 years of EMS versus TS data were available. Therefore, a crop simulation model was used to provide a longer series of soybean yields.

The objective of this research is to investigate the economic potential of early-maturing soybeans in southeastern Kansas. Specifically, effects of EMS on a representative farm will be evaluated in terms of impacts on returns, risk, and hired labor requirements.

Five steps were necessary to simulate a long-term series of soybean yields and to model crop production on a representative farm. First, a weather simulation model was used to generate weather data. Weather requirements for the crop simulation model (SOYGRO version 5.41) are daily maximum and minimum temperatures, daily precipitation, and solar radiation. In order to assess yield variability a long-term data series of 99 years was used. At the time simulations were in progress, the authors were not aware of such a long-term data series for southeastern Kansas. Thus, a weather generator, WGEN (Richardson and Wright), was used to provide simulated daily observations. (A series of temperatures and precipitation for Columbus, Kansas in Cherokee County from 1892 to 1987 is currently available; however, solar radiation data are still unavailable.)

Second, the simulated weather data were input into a crop simulation model (SOYGRO) to simulate 99 years of EMS and TS yields. SOYGRO (Jones et al.) uses five, general, location-specific parameters to simulate soybean growth. These five parameters are (1) soil profile characteristics; (2) daily weather data; (3) variety phenotypic information; (4) cultural practices; and (5) longitude and latitude. The soil type upon which the Southeast Kansas Branch Experiment Station is located, Parsons silt loam, was selected for soil characteristics. This study utilized the phenotypic data for Essex, for the group V soybeans grown in southeastern Kansas. Insufficient phenotypic information exists for a specific cultivar of group I that is currently grown in southeastern Kansas. Thus, a generic data set was used as provided by the SOYGRO program (Jones et al. p. 47). Cultural practices such as seeding rate, planting depth, planting date, row spacing, and plant density are based on the on-going EMS research at the Southeast Kansas Branch Experiment Station. Longitude (37.2N) and latitude (95.2W) of Parsons, Kansas were used to give the SOYGRO model solar data for day length and geographical position.

Simulated yields were higher than observed yields in southeastern Kansas. These higher yields may have occurred because the simulation model does not include impacts from disease and pest problems. The simulated yields were multiplied by 0.5940 to bring the mean of the 99 years to the observed mean of the traditional soybeans in the EMS study being conducted at the Southeast Kansas Branch Experiment Station. This was recommended by Dr. Richard Vanderlip, an agronomist at Kansas State University, who has considerable experience with crop simulation models. This adjustment provides reasonable yield levels and does not change the coefficient of variation. Because only 2 years of data (now 3 years) were available for the experiment comparing EMS and TS, no additional attempts were made to validate the soybean simulation model.

The 99 years of data were divided into ten 10-year periods (one year was used twice), so that two 10-year periods could be selected for whole-farm modeling. This was long enough to provide a distribution of yields but short enough not to be a burden for whole-farm modeling. An initial 10-year period selected was the one most like the 99-year period in terms of mean, standard deviation, variance, and proportion of years EMS out-yielded TS. The second 10-year period, selected for sensitivity analysis, was the one least favorable to EMS production, based on mean and standard deviation of yields (Table 1). If EMS are produced in the analysis based on data for the 10-year period least favorable to them, they will likely be produced in other periods.

Third, simulated yields and average or typical costs were used to prepare crop production budgets on the representative farm. Annual crop budgets were constructed to reflect returns over variable costs. Budgets for wheat and grain sorghum activities were also prepared to be included in the whole-farm model. Yields for wheat and sorghum were averages from performance tests. Output prices for soybeans were obtained from Grain and Feed Market News for the most recent 10 years. The prices for soybeans were from the predicted week of harvest for Kansas City, Kansas country elevators. For both grain sorghum and wheat, output prices were the averages for the month of harvest as reported in Agricultural Prices. To remove the impact of inflation, all output prices were adjusted to 1988 dollars using the Prices Received by Farmers Index.

The authors assumed that the representative farmer participates in the 1989 government program for wheat and feedgrain and that the cash price is equal to the average price from which the deficiency payment is calculated. This will generally result in a value of the deficiency payment per bushel being high, because payments under the government program are based on a formula using 5-month and 12-month average prices. Historically, the low for commodity prices is at harvest. The calculated deficiency payment is multiplied by the program yield and that value is added to cash receipts.

One consequence of using historical prices and simulated weather data is that output prices for soybeans do not follow simulated production patterns which are affected by weather. At the national level, prices would generally be expected to be negatively correlated with yields. At the farm level modeled here this relationship does not necessarily hold. The important relationship between soybean prices in August and October is captured by use of historical prices.

Yields for wheat and grain sorghum come from averages of Performance Tests conducted by Experiment Station personnel in southeastern Kansas for the past 10-years. Because soybean yields were simulated, the wheat and grain sorghum yields were independent from soybean yields. Variability of whole-farm income would likely be greater if soybean yields, wheat yields, and grain sorghum yields were based on the same weather data.

Variable input costs were in 1988 dollars. Input requirements for soybeans were obtained from the Southeast Kansas Experiment Station. Input requirements and costs for wheat and grain sorghum activities were obtained from 1988 KSU Farm Management Guides (Figurski and Schlender) and the Southeast Kansas Farm Management Association (Cooperative Extension Service). Discussions with scientists at the Southeast Kansas Experiment Station led to the selection of a representative machinery compliment for the representative crop farm to be modeled. Prices for the machinery and field time required to perform operations come from Fuller and McGuire.

Fourth, a linear programming (LP) model of a representative farm in southeastern Kansas was developed to determine if a profit-maximizing farm would raise early-maturing soybeans. The LP model is constructed so that the objective function is to maximize profit for five land use activities--early maturing soybeans, traditional soybeans, wheat, grain sorghum, and setaside acres. There are also weekly labor hiring activities for the months of April through October. The farm has a maximum of 700 acres of crop land and wheat and feedgrain bases typical of southeastern Kansas farms. Crop land and on-farm labor available are based on information from the Southeast Kansas Farm Management Association. Field work hours are included for the months of April through October. The field work days are calculated from 1982 through 1988 Crop-Weather reports published each week from farmer surveys by Kansas Agricultural Statistics. Hours available for field work per day are assumed to be 10 (Buller et al.).

Fifth, the profit maximizing model was modified to consider risk using the Target MOTAD methodology (Table 2). The objective function, five land use activities, and weekly labor hiring activities and associated constraints are the same as for the LP model. Ten constraint rows following the field time constraints relate annual gross margins from crop production and labor hiring activities to the target income. The 10 observations on annual income are treated as equally likely to occur. The last row in the matrix calculates the sum of annual negative deviations and provides a method of calculating alternative return and risk efficient solutions by changing the risk measure in the model, the variable D.

The target income selected for this study is based on data from the Southeast Kansas Farm Management Association. It is the summation of the following average data: family living expenses; income taxes; self employment taxes; life insurance; an estimate of long-term debt payments (principal and interest amortized over 15 years); an estimate of intermediate debt payments (principal and interest amortized over seven years); real estate taxes; personal property taxes; general farm insurance; and purchases of vehicles, machinery, equipment, and buildings. The target income was $63,658.

Results and Discussion

Target MOTAD models, representative of southeastern Kansas crop farms, are used to investigate economic incentives for adopting EMS. Five Target MOTAD model solutions are presented in Table 3. The three solutions based on the initial time period are (1) a base model in which EMS are not included as a production alternative, (2) the first feasible solution when EMS are included as an alternative, and (3) a solution with the same activity levels as the LP solution when EMS are included as an alternative. The two solutions based on the sensitivity analysis time period, both from models that allowed EMS as an alternative, are (4) the first feasible solution and (5) a solution with the same activity levels as the LP solution. A base model that does not allow EMS production for the sensitivity analysis is not necessary because no EMS were produced in solution 5.

Results are presented in terms of income above variable costs, acres of crop producing activities, risk levels, and hired labor. Results indicated that EMS, when incorporated into a representative southeastern Kansas crop farm, reduce risk and may increase or decrease income above variable costs (Table 3). Risk is measured as the total of annual negative deviations from a target income. The initial analysis is based on a 10-year period selected from the crop simulation results as most similar to the whole 99 years of simulations (Table 1). For the base model, when EMS are not included, income is $82,483 and risk is $946. For the LP solution when 67 acres of EMS are grown, income is $82,586 and risk is $614. Thus, the objective function is increased $103 and the risk measure is reduced $332. However, the differences in risk and returns are small relative to more than $82,000 of returns to fixed resources. Risk may be further reduced to $551 by increasing EMS production to 104 acres, but this lowers income to $82,549. Because the initial 10-year period solutions with EMS have higher income and lower risk than the solution without EMS, they are risk dominant over the solution in which EMS are not considered an alternative.

The sensitivity analysis is based on the 10-year period least favorable to EMS production in the 99-year simulation (Table 1). In the LP solution for this analysis, no EMS are produced. Despite the low average yield for EMS, risk can be reduced $331 if 34 acres of EMS are produced. But this reduction in risk is associated with a $1,432 reduction in income. Thus, if yields similar to those of the sensitivity analysis are expected, the operator's preferences for risk and returns are needed to determine whether to produce EMS.

One of the reasons why EMS are included in whole-farm plans is that soybeans sold in August have a price advantage. Research data indicate lower seed quality for EMS, which could result in a price discount. With the small quantity of EMS currently produced, it appears that prices of EMS are not being discounted for quality. However, if large numbers of farmers shift from production of TS to production of EMS, then because of lower seed quality and larger quantities of soybeans available early, the price advantage for EMS would likely diminish or disappear.

Incorporation of EMS by a representative southeastern Kansas crop farm reduces hired labor required during the cropping season; however, the reduction in total annual hours of hired labor is small (Table 4). The total annual difference between the initial 10-year period model in which 104 acres of EMS were produced and the model with no EMS was 47 hours. If 104 acres of EMS were produced, 17 fewer hours of hired labor were required during the second week in June and the third week in October. If the operator provides all the labor to the farm, these labor savings might be significant.

Summary and Conclusions

The objective of this research was to investigate the economic potential of early maturing soybeans (EMS). Weather simulation and crop simulation models were used to generate yields. Target MOTAD was used to model a representative crop farm in southeastern Kansas. The farm participated in the 1989 government program for wheat and feedgrain.

Inclusion of EMS in farm plans reduces risk. However, the reductions in risk may come with an increase or a decrease in income. The reductions in risk are small when compared to the returns to fixed resources of the representative farm. EMS also reduces hired labor required during the cropping season. Thus, reductions in risk and labor required during critical time periods provide incentives for diversification into EMS. The operator's preference for risk versus returns and labor available in critical time periods will determine how many acres of EMS and traditional soybeans are planted.

These preliminary conclusions are based on simulated soybean yield data. Because only 2 years of experimental soybean yield data were available when the yield simulations were performed, the crop simulation model was not formally validated for southeastern Kansas. Use of historical soybean prices and simulated yields based on simulated weather data along with historical price and yield data for wheat and grain sorghum casts some doubt on the measure of income variability. However, a study based on a 2-year average of actual data would have been questionable, and a formal risk analysis based on 2 years of data would have been illogical. More information is needed to better evaluate the simulated yields. But we can conclude from the study that further research on early maturing soybeans is warranted and that early maturing soybeans may provide a diversification strategy for risk-averse farmers.

Table 1. Summary of Two Ten-year Periods and 99 years of Soybean Yield Simulations

Year	Traditional Soybean Yield	Early Maturing Soybean Yield
	- - - - Bushels/Acre-	- - - -
Ten-year period with simulations most liked 99-years of simulations		
1	24.7	31.3
2	23.9	35.5
3	24.5	15.0
4	35.7	35.0
5	33.1	33.1
6	25.3	21.0
7	32.0	35.3
8	30.8	22.5
9	32.6	34.3
10	35.5	32.4
Mean	29.8	29.5
Standard Deviation	4.5	6.9
Ten-year period selected for sensitivity analysis		
1	35.5	35.3
2	34.0	33.3
3	32.4	17.4
4	31.9	23.6
5	31.0	0.0
6	29.0	28.0
7	8.9	13.0
8	34.9	18.6
9	22.0	29.7
10	33.6	33.4
Mean	29.3	23.2
Standard Deviation	7.8	10.6
Ninety-nine years		
Mean	27.8	27.1
Standard Deviation	7.5	7.6

TABLE 2. Simplified Target MOTAD Model[a]

	Activities							
Constraints	EMS	TS	Wheat	Sorghum	Setaside	Hiring Labor	Negative Deviations	Righthand Side
Max. Return OBJ	+	+	+	+	-	-		
Land	+	+	+	+	+			+
Wheat base			+					+
Feed grain base				+				+
Setaside					+			+
Field Time	+	+	+	+		-		+
Annual Income	+	+	+	+	-	-	-	Target
Risk							-1	D

[a]Sign convention: (+) indicates income or usage, (-) indicates cost or supply. There are 31 weekly labor hiring activities. There are 10 annual negative deviations. There are 31 weekly field time constraints. There are 10 annual incomes.

Table 3. Objective Function, Land Use Activities and Risk for Solutions from Target MOTAD Models of a Representative Crop Farm in Southeastern Kansas.[a]

	Models Including EMS as an Alternative				
	Initial Analysis			Sensitivity Analysis	
	Model without EMS	First Feasible Solution	LP Solution	First Feasible Solution	LP Solution
Objective Function	$82,483	$82,549	$82,586	$80,295	$81,727
Acres EMS	0	104	67	34	0
Acres TS	210	106	143	176	210
Risk Measure	$946	$551	$614	$2,617	$2,948

[a]Other solutions are not reported because differences from reported solutions are small. Choice of solutions for reporting is based on the operations of the target MOTAD model. When the level of risk is set at low levels, solutions are infeasible. When the level of risk is set at high levels, activity levels are the same as those for the LP solution. For the model without EMS the first feasible solution is identical to the LP solution. EMS is an abbreviation for early-maturing soybeans, TS for traditional soybeans. The objective function maximized returns above variable costs. Fixed resources include land, operator labor and management, machinery, buildings, and equipment. The measure of risk is the total of annual negative deviations from a target income. In accordance with the 1989 U.S. commodity program and base acreages on the 700 acre farm, all solutions contained 252 acres of wheat, 189 acres of grain sorghum, and 49 acres of setaside. Results are rounded to the nearest whole number.

Table 4. Labor Hiring Activities for Solutions from Target MOTAD Models of a Representative Crop Farm in Southeastern Kansas.

		Models Including EMS as an Alternative			
		Initial Analysis		Sensitivity Analysis	
Weeks[a]	Model without EMS	Solution with 104 Ac. of EMS	Solution with 67 Ac. of EMS	Solution with 34 Ac. of EMS	Solution with 0 Ac. of EMS
April W3	31.29	28.60	29.55	30.40	31.29
April W4	6.88	8.22	7.75	7.32	6.88
June W1	61.44	61.44	61.44	61.44	61.44
June W2	17.40	0	0	8.54	17.40
June W3	6.75	6.75	6.75	6.75	6.75
June W4	30.56	30.55	30.56	30.56	30.56
Oct. W2	11.19	0	0	5.43	11.19
Oct. W3	51.41	33.94	40.10	45.65	51.41
Oct. W5	7.88	7.88	7.88	7.88	7.88
Total Hours Hired	224.80	177.38	184.03	203.97	224.80

[a] April W3 means the third week in April, etc.

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