Identifying Threshold Technical Advances Required for Incorporating Alternative Crops Into Current Crop Mixes

M. Edward Rister
Matthew Stockton
James W. Richardson
Gregory M. Perry
David A. Bessler
John E. Matocha
John Bremer
Steve Livingston
Lucas Reyes
James Novak

Presented paper at the 1987 American Agricultural Economics Association meetings in East Lansing, Michigan during August 2-5, 1987. The authors are, respectively, Associate Professor, Research Associate, and Professor of the Texas Agricultural Experiment Station, Assistant Professor in the Department of Agricultural Economics at Oregon State University, Professor of the Texas Agricultural Experiment Station, all agricultural economists; Professor of Soil Science, Extension Agronomist, Extension Agronomist, and Crop Scientist, all of the Texas Agricultural Research and Extension Center at Corpus Christi; and Extension Economist, Auburn University. This research was funded by the Texas Agricultural Experiment Station (Project H6507). Comments and suggestions at various stages of this research project by Jess Person, Wayne Mengers, Bobby Nedbalek, Jimmy Dodson, David Mayo, Hilmer Person, Harvey Buehring, and Darwin Anderson are gratefully acknowledged. The typing assistance of Kelli Barker and Shauna Smith is sincerely appreciated.

Identifying Threshold Technical Advances Required for Incorporating Alternative Crops Into Current Crop Mixes

ABSTRACT

Prospects for incorporating a currently non-competitive alternative crop into agricultural producers' annual crop mix portfolio are investigated. Through iterative use of a whole farm simulation model, it is demonstrated Texas Coastal Bend soybean yields must increase in excess of 50% to economically compete with present grain sorghum and cotton acreage.

The magnitude of dominance represented by the results reported in Table 1 prompted several questions amongst area producers and concerned scientists. A primary issue is with regard to the level of yield increase required for a challenging crop to become an economical viable contender for acreage currently being planted to grain sorghum and/or cotton. Producers' interest in this question is associated with a desire to identify the yield threshold (i.e., trigger point) at which they should become serious regarding incorporating a challenging crop into their crop mix strategies. Scientists, while interested in the same question for similar reasons, are also motivated by a need to identify the resources required to develop new varieties and/or crop management systems contributing to enhanced economic viability of producers and, ultimately, more economically affordable food for society. It is probable that a significantly positive correlation exists between required resources and needed yield increases. Consequently, research scientists and their administrators, when confronted with allocating limited funding support, should be aware of the relative technology breakthrough required in different areas. This paper offers a proposed approach for addresssing the threshold level of yield advance required for a challenging alternative crop, using the aforementioned Texas Coastal Bend crop mix study for illustration purposes. Due to space considerations, results are demonstrated only for soybeans.

Methodology

A major obstacle encountered in evaluating the potential economic contributions of the challenging crops relative to those of the traditional ("defending") crops was lack of suitable data regarding probable harvested yield levels associated with each of the five crops under various crop rotation strategies. At the time of the initial interest in this topic,

Identifying Threshold Technical Advances Required for Incorporating Alternative Crops Into Current Crop Mixes

Introduction

Prevailing economic conditions in the agricultural industry are encouraging both producers and research scientists to closely evaluate current and potential production, marketing, and financial alternatives. Among the several areas receiving increased management attention is that of crop mixes. This paper represents a partial report of a research study directed towards evaluating the economics of several existing and contemplated crop rotations in Nueces and San Patricio counties located near Corpus Christi in the Texas Coastal Bend region.

Traditional crop rotations in the study area are heavily dependent on grain sorghum and cotton acreage. In recent years, however, substantial interest has been directed towards the prospects for several challenging alternative crops, including corn, soybeans, and wheat. In an earlier phase of the research study with which this paper is associated, the authors noted the consideration of eighteen different crop rotations, each comprised of one or more of the aforementioned five crops (Exhibit 1). Approaching the issue through simulation of a hypothetical farm operation, the authors reported the dominance of currently observable existing crop rotations comprised of grain sorghum and cotton (i.e., b's 18, 2, and 3) over the several other possibilities including, to varying extents, one or more of the challenging crops (Table 1.)

relatively little objective data was available regarding the potential productivity of any of the challenging crops, especially in terms of their performance as part of a long-term rotation.

The significant variability of relevant weather factors in the study region combined with the potential rotation effects of different crop mixes dictate a field experiment of considerable duration (years) is required to discern the probable yield distributions associated with each crop in various crop rotations, thereby delaying the delivery of timely information to interested producers. Moreover, the vast number of crop rotation possibilities associated with these five crops further contributes to a logistic laden, cost prohibitive traditional field experiment research problem. To overcome this impediment, a Delphi approach was used with resident soil and crop scientists and area farmers to identify several crop rotations considered to be most technically feasible for the study region (Exhibit 1).

Subsequently, a subjective elicitation procedure (Bessler) was employed to identify probable yield distributions for each crop associated with each respective crop rotation. This latter elicitation procedure involved both personal and mail interviews with four resident professional soil and crop scientists (i.e., the "experts") and five area farmers (i.e., the "producers"), the latter group being characterized as above-average agricultural managers. Each of these individuals initially identified the range and frequency of harvested yield outcomes he considered probable for each crop over a lengthy tenure of following the respective crop rotations. Following review of the average results across members of the other group (i.e., each producer reviewed the average statistics provided by the experts and vice versa), each individual was allowed to revise his subjective expectations. Pooled cross-section representation of the nine individuals' revised subjective yield distributions was considered to comprise the opportunity set of possible yield outcomes for each production scenario.

Using the above described harvested yield data, simulation modeling was utilized to investigate the economic merits of the respective eighteen crop rotations for a hypothetical case farm situation in the Texas Coastal Bend region. Using the FLIPSIM V model previously developed by Richardson and Nixon, the economic performance of a 2000 acre farming operation was analyzed over a five year period (1986-1990) for each of the specified eighteen crop rotation production scenarios. The FLIPSIM V model is a firm level, recursive, Monte Carlo simulation model that simulates annual production, farm policy, marketing, management, and income tax aspects of a farm over a chosen planning horizon. The model recursively simulates the farming operation by using the current year's ending financial position as a beginning financial position for the next year. The Monte Carlo aspect of the model comes from repeating (iterating) simulations of farm operations over the planning horizon many times (i.e., 100 iterations in this study), using pseudo-random crop prices and yields drawn from a multivariate empirical probability distribution for these variables.

In addition to the previously described harvested yield data, several other sets of data were required for use in the FLIPSIM V generated economic analysis. Stochastic market price outcomes were developed for 1986-1990, based on historical area market performance and interviews with experts (Smith; Anderson; Feagan). The 1985 Farm Bill's features of declining loan rates and target prices were incorporated into the analysis (USDA) along with appropriate adjustments for local loan rates; similarly, set-aside provisions of 20-35% are embodied in the analysis. In recognition of the hypothetical farm's size (i.e., 2000 acres) and contemporary local business organization structures, it was assumed two individuals were qualified for government payments, thereby establishing an upper limit of $100,000 for receipt of annual government payments.

Several sets of assumptions relating to future macroeconomic factors were developed based on results from the COMGEM model (Penson et al.; Penson). In general, land values were assumed to remain constant over the study period, variable production costs averaged increasing at an annual rate of 4.25%, capital interest rates declined, new machinery prices increased, and used machinery values declined. Regarding the taxation of annual realized net farm income, the provisions of the 1984 Tax Reform Act were assumed throughout the study period.

Several other assumptions are germane to the particular hypothetical farm analyzed. The 2000 acre operation was assumed to be supporting one and a half households, with total annual living expenses varying between $30,000 and $75,000, such variance being positively correlated with farm income. Annual off-farm income was assumed to be $12,000. An initial equity position of 50% of total asset value was assumed. Total value of machinery assets varied slightly across the eighteen crop rotation production scenarios, according to the specific harvesting machinery requirements associated with the respective crop acreages comprising each rotation. A part-owner situation was assumed, with 25% of the farmed acreage being owned and the remaining 75% of the acreage farmed on a share-rental arrangement basis. Variable production costs associated with each crop in each rotation are based on quantity estimates by area producers relating to the respective variable inputs and area input prices identified by local suppliers. Chemical costs for each crop vary according to the specific rotation, based on the relevant agronomic considerations.

FLIPSIM V's explicit consideration of the dynamic nature of harvested yields and market prices in conjunction with the several other relevant factors facilitated identification of 100 sets of the hypothetical farm's financial performance over the 1986-1990 study period for each of the eighteen crop rotation production scenarios. Average net present value (NPV) of earnings for the five year planning horizon are analyzed to evaluate the performance of each rotation.

The NPV for the farming operation represents the present value of ending net worth for the farm, plus yearly family withdrawals discounted to the present, minus beginning net worth and discounted annual off-farm income. In this paper, evaluation of the NPV's associated with the respective eighteen crop rotation production scenarios are based on the average value (across the 100 iterations) of such individual iteration NPV values.

The above discussion of methodology relates both to the base results reported in Table 1 and the sensitivity results associated with this paper's focus. To ascertain the threshold yield advance required for soybeans to become an economic viable contender, the simulation procedure was repeated for soybeans with the soybean yield distribution shifted upward (i.e., to the right) by first 25%, then by 50%, and finally by 100%. The base soybean yield distributions tended to average approximately 23 bushels per acre with a coefficient variation of 2.5; some variance in these statistics were observable across the subjective estimates for the respective rotations including soybeans.

Such yield shifts are intended to represent technological induced increases resulting from improved varieties and/or enhanced crop management systems. It is further assumed that such technical advances are both crop and site specific. Consequently, the production of the other crops comprising the several rotations considered and the macro-market price of soybeans are both assumed to be at levels similar to those of the base analysis. (With respect to the latter assumption, if such was not the case, linkage with a macro-market model would be appropriate to reflect the firm level aspects of the macro impact.)

Results

Ranked simulation results associated with increasing soybean yields by 25%, 50%, and 100% above base levels are reported in table 2. As expected, NPV of earnings increased for all rotations including soybeans (i.e., #'s 4, 8, 9, 10, 12, 13, and 14) while the measure remained the same for all other rotations (since their performance was assumed to be unaffected by the technical advancement in soybeans). Furthermore, the increase in NPV of earnings was more dramatic as the portion of acreage within a rotation that was allocated to soybeans increased. For example, when soybean yields were increased by 25%, NPV of earnings for rotation #4 (1/2 grain sorghum, 1/2 soybeans) increased by over $130,000 while an increase of only $31,680 was observed for rotation #15 (only 1/6 soybeans). Similar differences in magnitude of change were observed for the other rotations including soybeans and at the other rates of increased soybean yields (Table 2).

25% Increase in Soybean Yields

Relative to the base results reported in table 1, a 25% increase in soybean yields enhanced the NPV ranking of only three of the eight rotations including soybeans, i.e., #'s 13 (moved from 4th to 3rd), 14 (moved from 9th to 7th), and 10 (moved from 13th to 11th). Recognizing the gross differences in average NPV values observable throughout the ranked 18 rotations (table 2), it must be recognized that only rotation #13 can be considered as becoming a viable contender to the predominant rotations #'s 18, 3, and 2. It should be noted that while the discussion presented in the paper relies heavily on rankings of average NPV of earnings calculated across the 100 iterations of the simulation analyses, more robust evaluation utilizing stochastic dominance decision criteria applied to the respective cumulative distributions of NPV of earnings results in somewhat similar conclusions. In addition, probabilities of survival and success values are similarly supportive of the results presented herein.

It is imperative that the perspective of soybeans be fully realized when evaluating these results. As inferred in table 1, the relative performance of the respective rotations is dependent, in part, on the level of annual government payments received by the business. Of the five crops comprising the various rotations, soybeans are eligible for receiving the least government support when adverse market conditions occur. Accordingly, rather significant yield increases should be anticipated as being necessary to displace grain sorghum and cotton acreage, assuming the status quo on all other factors of relevance.

50% Increase in Soybeans Yield

Again, some relative net gain in average NPV of earnings is realized when soybean yields are increased 50% above the base study levels. Rotation #13 continues to emerge as the most competitive contender, with #8 also benefiting in an improvement of ranking. Rotation #'s 14 and 10 also appear more competitive in this scenario.

100% Increase in Soybeans Yields

Assuming rather dramatic (i.e., 100%) yield enhancements occur for soybeans with all other factors held constant, rotation #'s 13 and 8 emerge as the most profitable, on the average, among the respective eighteen rotations considered. The magnitude of superiority on the basis of average NPV of earnings is approximately $36,000 for #13 and $15,000 for #8, relative to rotation #18. These results infer that yield increases of somewhat less than 100% but above 50% are required for soybeans to become a viable economic alternative for Texas Coastal Bend agricultural producers.

Conclusions

Previous agricultural research has documented the ramifications of forthcoming technological advances (Office of Technology Assessment). Related studies have exposed the potential viability of various types of farming operations assuming occurrence of various economic scenarios (e.g., Helms; Pfleuger and Barry). This paper approaches agricultural producers' future viability from a somewhat similar but different approach, attempting to identify those threshold levels of yield advances required to displace current prevailing production enterprises with challenging alternatives. Recognizing the current significant interest in alternative enterprises (Successful Farming), it is proposed that macro issues similar to those noted by Debertin be linked to the type of analysis presented herein. The results of such holistic research should be insightful to both producers and researchers as well as to administrators and policymakers.

Exhibit 1. Eighteen technically feasible crop rotations for Nueces and San Patricio Counties in the Texas Coastal Bend region

Rotation #	Crops (A)
1	GS
2	GS - CTN
3	GS - GS - CTN - CTN
4	GS - SOY
5	CRN
6	CRN - CTN
7	CTN
8	GS - GS - CTN - SOY
9	GS - GS - W - SOY
10	GS - GS - W/SOY
11	GS - CRN
12	GS - W/SOY - GS - CRN
13	GS - GS - CTN - W/SOY
14	CRN - GS - GS - CTN - SOY
15	CRN - GS - GS - W - SOY - CRN
16	CRN - GS - GS - W - CTN
17	GS - GS - CRN
18	GS - GS - CTN

(A) The abbreviations cited reflect the individual crop(s) comprising the respective rotations. When only one crop is identified, 100% of a farm's acreage is annually planted to that crop (allowing for government farm program participation); when two crops are identified, 50% of a farm's acreage is planted to each; etc. For any particular acre or tract of ground on a farm, the cropping pattern followed over time (years) is represented by the respective designated crop sequences. The abbreviations designated correspond to the respective crops as follows:

CRN - corn SOY - soybeans
CTN - cotton W - wheat
GS - grain sorghum

Furthermore, where the "/" symbol is used to separate two crops (i.e., W/SOY), this is reference to a double cropping regime of the respective crops within a single year.

Table 1. **Baseline economic ranking of eighteen alternative crop rotation production scenarios for the Texas Coastal Bend Region (Nueces and San Patricio Counties).**

Rotation #	Crop Sequence (A)	P(Survival) (%)	NPV ($1,000)	P(Success) (%)	Annual Gov't Payments ($1,000)
18	GS-GS-CTN	100	205.9	100	104.4
2	GS-CTN	100	144.7	99	113.0
3	GS-GS-CTN-CTN	100	103.1	98	113.5
13	GS-GS-CTN-W/SOY	100	86.7	85	90.1
8	GS-GS-CTN-SOY	100	50.2	74	80.9
7	CTN	100	32.9	56	126.9
6	CRN-CTN	100	22.9	56	110.3
16	CRN-GS-GS-W-CTN	100	11.0	50	72.3
14	CRN-GS-GS-CTN-SOY	100	-13.8	38	74.3
15	CTN-GS-GS-W-SOY-CRN	99	-30.1	36	68.1
1	GS	93	-50.3	31	62.0
17	GS-GS-CRN	90	-68.7	30	57.3
11	GS-CRN	85	-95.0	26	55.2
10	GS-GS-W/SOY	93	-81.3	17	53.7
12	GS-W/SOY-GS-CRN	72	-185.6	9	52.4
5	CRN	20	-377.9	4	47.5
9	GS-GS-W-SOY	70	-201.9	2	40.6
4	GS-SOY	24	-296.7	0	32.7

(A) The abbreviations designated correspond to the respective crops as follows:

CRN - corn
CTN - cotton
GS - grain sorghum
SOY - soybeans
W - wheat

Furthermore, where the "/" symbol is used to separate two crops (i.e., W/SOY), this is reference to a double cropping regime of the respective crops within a single year.

Table 2. Ranking of Simulated Sensitivity Analyses of Eighteen Alternative Crop Rotation Production Scenarios for the Texas Coastal Bend Region (Nueces and San Patricio Counties), Increased Soybean Yields.

Soybean Yield Increases								
25%			50%			100%		
Base NPV Rank	Crop Rotation/ Sequence	NPV ($1000)	Base NPV Rank	Crop Rotation/ Sequence	NPV ($1000)	Base NPV Rank	Crop Rotation/ Sequence	NPV ($1000)
1	(18) GS-GS-CTN	205.	1	(18) GS-GS-CTN	205.	4	(13) GS-GS-CTN-W/SOY	242.
2	(2) GS-CTN	144.	4	(13) GS-GS-CTN-W/SOY	166.	5	(8) GS-GS-CTN-SOY	221.
4	(13) GS-GS-CTN-W/SOY	126.	2	(2) GS-CTN	144.	1	(18) GS-GS-CTN	205.
3	(3) GS-GS-CTN-CTN	103.	5	(8) GS-GS-CTN-SOY	137.	13	(10) GS-GS-W/SOY	160.
5	(8) GS-GS-CTN-SOY	94.	3	(3) GS-GS-CTN-CTN	103.	2	(2) GS-CTN	144.
6	(7) CTN	32.	9	(14) CRN-GS-GS-CTN-SOY	60.	17	(4) GS-SOY	136.
9	(14) CRN-GS-GS-CTN-SOY	23.	13	(10) GS-GS-W/SOY	46.	9	(14) CRN-GS-GS-CTN-SOY	133.
7	(6) CRN-CTN	22.	6	(7) CTN	32.	3	(3) GS-GS-CTN-CTN	103.
8	(16) CRN-GS-GS-W-CTN	11.	10	(15) CTN-GS-GS-W-SOY-CRN	32.	10	(15) CTN-GS-GS-W-SOY-CRN	92.
10	(15) CTN-GS-GS-W-SOY-CRN	1.	7	(6) CRN-CTN	22.	6	(7) CTN	32.
13	(10) GS-GS-W/SOY	-14.	8	(16) CRN-GS-GS-W-CTN	11.	16	(9) GS-GS-W-SOY	23.
11	(1) GS	-50.	17	(4) GS-SOY	-44.	7	(6) CRN-CTN	22.
12	(17) GS-GS-CRN	-68.	11	(1) GS	-50.	15	(12) GS-W/SOY-GS-CRN	14.
14	(11) GS-CRN	-95.	12	(17) GS-GS-CRN	-68.	8	(16) CRN-GS-GS-W-CTN	11.
15	(12) GS-W/SOY-GS-CRN	-126.	16	(9) GS-GS-W-SOY	-69.	11	(1) GS	-50.
17	(9) GS-GS-W-SOY	-128.	15	(12) GS-W/SOY-GS-CRN	-77.	12	(17) GS-GS-CRN	-68.
16	(4) GS-SOY	-166.	14	(11) GS-CRN	-95.	14	(11) GS-CRN	-95.
17	(5) CRN	-377.	18	(5) CRN	-377.	18	(5) CRN	-377.

References

Anderson, C. 1986. Personal interview. Texas Agricultural Extension Service Cotton Marketing Specialist, College Station, TX.

Bessler, D. A. 1977. "Foresight and Inductive Reasoning: Analysis of Expectations on Economic Variables with California field crops," Unpublished Ph.D. dissertation, University of California, Davis.

Debertin, D. L. "Why Specialty Farming Can't Work for Everyone," Choices, 4th Quarter, 1986, p. 22.

Feagan, J. 1986. Personal interview. Texas Agricultural Extension Service Oilseeds Marketing Specialist, College Station, TX.

Helms, G. L. "Economic Simulation of Selected Production and Marketing Strategies for Three Typical Farms and Ranches in Northern Utah", Unpublished M.S. Thesis, Department of Agricultural Economics, Utah State University. 1985.

Office of Technology Assessment. Technology, Public Policy, and the Changing Structure of American Agriculture -- A Special Report for the 1985 Farm Bill. OTA-F-272, March 1985.

Penson, J. B. 1983. Unpublished data. Department of Agricultural Economics, Texas A&M University, College Station, TX.

Penson, J. B., D. W. Hughes, and R. F. J. Romain. 1984. "An Overview of COMGEM: A Macroeconomic Model Emphasizing Agriculture", DIR 84-1, SP-12, Texas A&M University, College Station, TX.

Pfleuger, B. W., and P. J. Barry. "Crop Insurance and Credit: A Farm Level Simulation Analysis", Agricultural Finance Review. 46(1986):1-14.

Richardson, J. W. and C. J. Nixon. 1986. "Description of FLIPSIM V: A General Firm Level Policy Simulation Model", Texas Agricultural Experiment Station, Bulletin 1528. College Station, TX.

Smith, E. G. 1986. Personal interview. Texas Agricultural Extension Service Grain Marketing Specialist, College Station, TX.

Successful Farming, "How to Diversify Your Farm This Year." February 1987, pp. 11-18.

U. S. Department of Agriculture. 1986. "Highlights of the Food Security Act of 1985", P. L. 99-198. ASCS press release PR #10.