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INTEGRATING ECONOMIC ANALYSIS WITH BIOPHYSICAL SIMULATION: APPRAISING BLACKLAND CORN PRODUCTION

The Texas Agricultural Experiment Station, Charles J. Arntzen, Director
The Texas A&M University System, College Station, Texas

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Carl R. Dillon
James W. Mjelde
Bruce A. McCarl
J. Tom Cothren
J. Rod Martin
M. Edward Rister
Claudio Stockle

The authors are, respectively: research associate, assistant professor, and professor in the Department of Agricultural Economics; associate professor in the Department of Soil and Crop Sciences; professor and associate professor in the Department of Agricultural Economics, Texas A&M University, and assistant professor, Texas Agricultural Experiment Station, Blackland Research Center.

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INTEGRATING ECONOMIC ANALYSIS WITH BIOPHYSICAL SIMULATION: APPRAISING BLACKLAND CORN PRODUCTION

Abstract

Farmers continually face difficulties to overcome and new production opportunities to consider. Increased corn acreage in the Texas Blackland Prairie has indicated this enterprise is a feasible production alternative to other major crops of the area. This report describes (1) research on the economic feasibility of Blackland corn production and (2) the usefulness of four biophysical simulation models developed at the Blackland Research Center (CORNF, SORGF, TAMW, and COTTAM). First, the agronomic effects of planting dates, plant populations, and maturity classes on yields of corn, grain sorghum, wheat, and cotton are examined. Second, the economic consequences of differences in producers' attitudes toward risk, corn price, and corn production practices on decision making and profit are investigated.

Yield responses from the biophysical simulation models are incorporated into an economic decision model. Quadratic programming is used to model a hypothetical Blackland farm. Given the various scenarios analyzed, all four crops are economically feasible for the Blackland. Cotton is an especially economically lucrative production activity. Reduction of risk is accomplished by including wheat in the crop mix and by lowering the plant population of corn. Corn and grain sorghum production are highly substitutable. Analysis of corn production practices indicates that profit effects attributed to changing corn planting dates are more pronounced than profit changes resulting from other production practices analyzed. This indicates that farmers should give careful consideration to planting date with respect to corn production decisions because greater gains or losses can occur from this decision.

Keywords: Corn, economics, biophysical simulation, risk analysis, mathematical programming

INTEGRATING ECONOMIC ANALYSIS WITH BIOPHYSICAL SIMULATION: APPRAISING BLACKLANDS CORN PRODUCTION

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I. Introduction

Farmers continually seek to take advantage of new opportunities to remain economically viable and competitive. One such opportunity involves the production of corn on the Blackland prairie of Texas. In recent years, hybrids have been developed which are well suited for this region (Coffman 1987). Consequently, increasing Blackland acreage has been devoted to corn (Parker et al. 1986), and there is potential for yet more corn production. One issue regarding corn relates to its proper role in the crop mix. In addition, corn can be grown under many different practices regarding planting date, plant population, maturity class, and other production considerations. Choice among these production options constitutes a second important issue.

The economic analysis of corn production is complicated by the limitations of available production data. Biophysical simulation serves as a potential method of alleviating certain limited production data problems. The objectives of this study were to (1) provide economic analyses of the corn production enterprise to assist Blackland crop producers in decision making and (2) appraise the usefulness of a set of biophysical simulation models developed at the Blackland Research Center in conducting these analyses.

To satisfy the objectives, several steps were undertaken.

A. The agronomic effects of production management practices on yield were examined utilizing biophysical simulation models developed at the Texas Agricultural Experiment Station (TAES) Blackland Research Center.

   1. Biophysical simulation models were used to generate production data.
   2. Statistical analyses of the biophysical simulation model results were conducted to provide insight into the influence of certain production management practices on yield.

B. The economics of the Blackland cropping system were investigated based on growth simulation results and included the following study components associated with economic analyses.

   1. Characteristics of an economically optimum crop mix were analyzed.
   2. The effects of differences in attitudes toward production risks were analyzed.
   3. The effects of corn price changes on production decisions were studied.
   4. The economic effects of using alternative corn production management practices were studied. These included the planting date, plant population, and maturity class of corn.

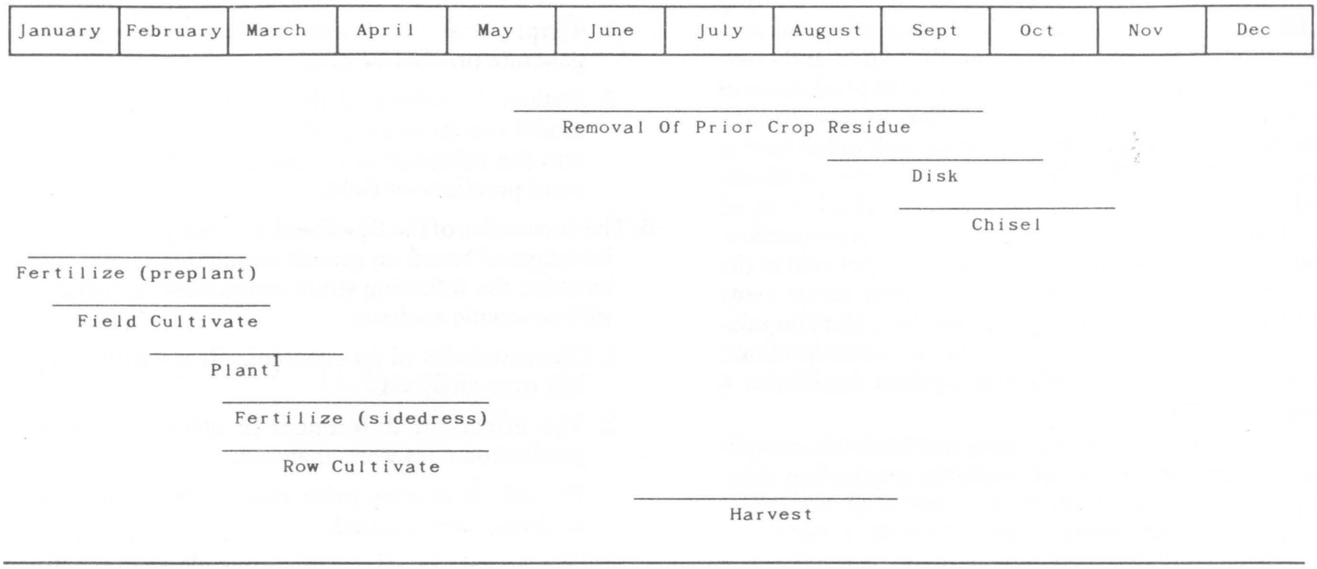
The remainder of this report is organized as follows. First, background information on Blackland crop production is provided. The general methodological approach, data sources, and analysis conducted are then discussed. Subsequently, the agronomic and economic results are discussed followed by a summary and conclusions.

II. Background Information

This study considers the four major crops grown in the Blackland region of Texas: corn, grain sorghum, wheat, and cotton. Climatic data used are daily minimum and maximum temperature and precipitation for the 38-year period between 1949 to 1986.

The production processes of Blackland crop production involve several stages. The assumed production operation decision timeline for corn is given in Figure 2.1, grain sorghum in Figure 2.2, wheat in Figure 2.3, and cotton in Figure 2.4. Each figure depicts chisel-type, flat planting conventional tillage systems. These tillage systems were developed at the Blackland Research Center (Morrison et al. 1988). Their development concept included advanced management with optimum tillage and other inputs. These conventional tillage systems were developed to serve as a check, control, or standard of comparison in a comparative analysis of no-tillage systems and the "best" conventional tillage systems for the Blackland farming area. The systems employed for each crop in the present study are explained further in Dillon (1987).

During the course of a crop year, a farmer utilizes resources to produce a crop. Decisions are made based upon expected returns and costs. Therefore, expected levels of yields, product prices, input requirements, and input prices are needed. Further, yields are a function of weather and production management decisions and are therefore risky.

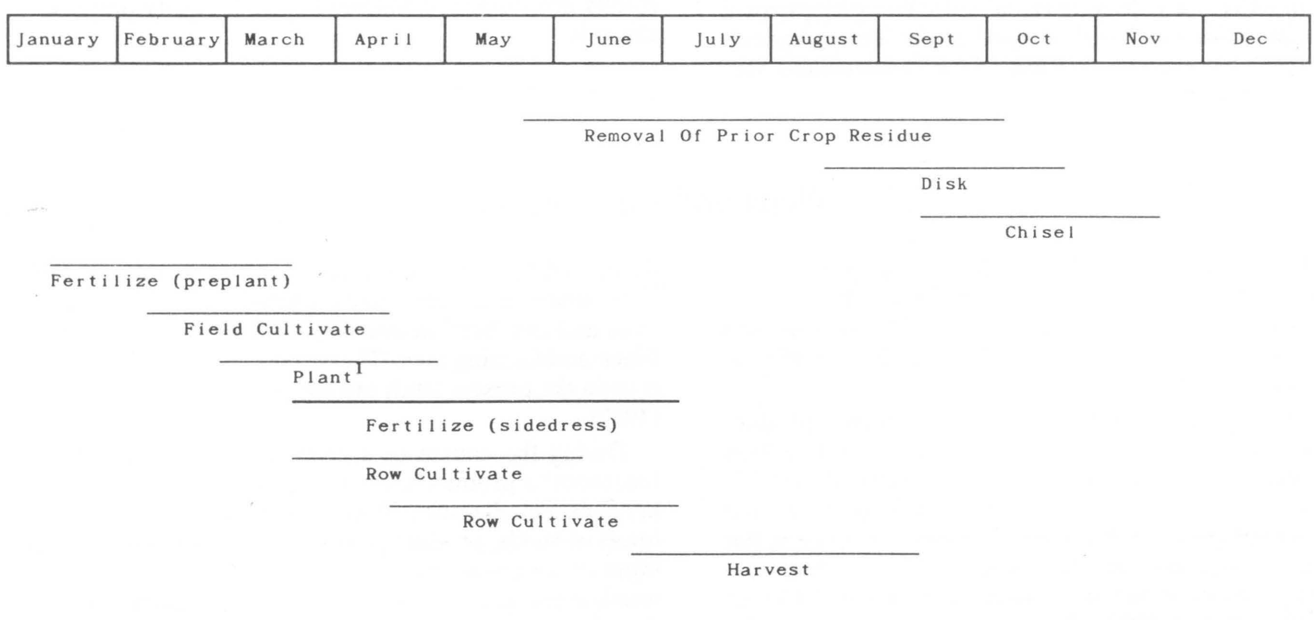


SOURCE: Morrison et al. (1988)

[1]The planting operation includes fertilization, application of herbicide, and application of insecticide.

NOTE: A chisel-type flat planting conventional tillage system for the Blackland area is depicted. Preharvest custom operations are excluded because they are not performed by the production management decisionmaker. Harvest is also performed on a custom basis but is included as it influences timing of preparation for later crops.

Figure 2.1. Corn Machinery Activity Decision Timeline.

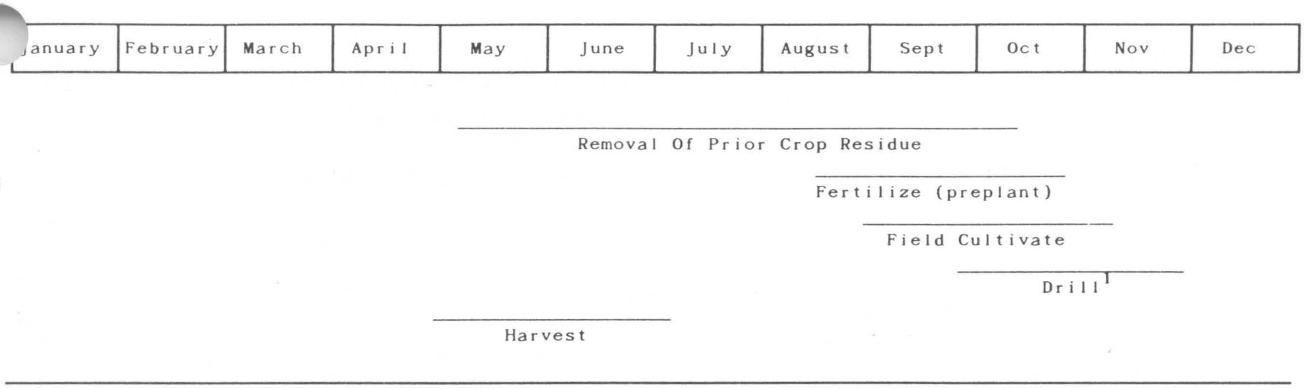


SOURCE: Morrison et al. (1988)

[1]The planting operation includes fertilization, application of herbicide, and application of insecticide.

NOTE: A chisel-type flat planting conventional tillage system for the Blackland area is depicted. Preharvest custom operations are excluded because they are not performed by the production management decisionmaker. Harvest is also performed on a custom basis but is included as it influences timing of preparation for later crops.

Figure 2.2. Grain Sorghum Machinery Activity Decision Timeline.

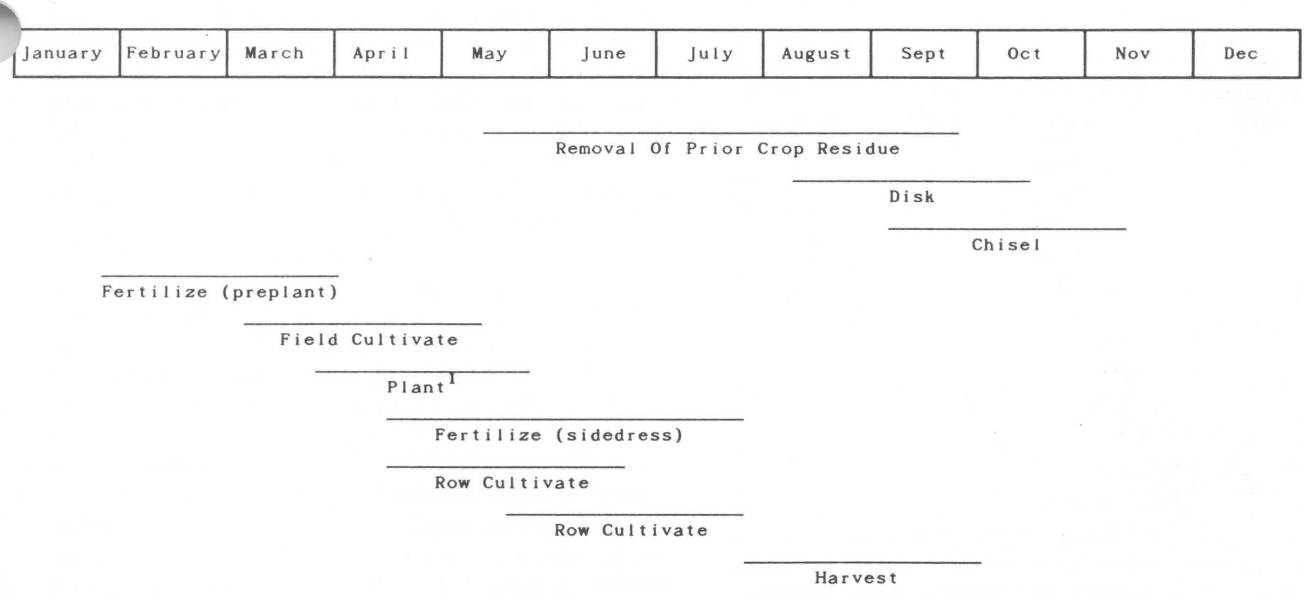


SOURCE: Morrison et al. (1988)

[1]The drilling operation includes fertilization, application of herbicide, and application of insecticide.

NOTE: A chisel-type flat planting conventional tillage system for the Blackland area is depicted. Preharvest custom operations are excluded because they are not performed by the production management decisionmaker. Harvest is also performed on a custom basis but is included as it influences timing of preparation for later crops.

Figure 2.3. Wheat Machinery Activity Decision Timeline.



SOURCE: Morrison et al. (1988)

[1]The planting operation includes fertilization, application of herbicide, and application of insecticide.

NOTE: A chisel-type flat planting conventional tillage system for the Blackland area is depicted. Preharvest custom operations are excluded because they are not performed by the production management decisionmaker. Harvest is also performed on a custom basis but is included as it influences timing of preparation for later crops.

Figure 2.4. Cotton Machinery Activity Decision Timeline.

III. Procedures and Data

This study employs simulated data to describe the cropping alternatives and the available working time. The simulated data are then incorporated into an economic decision model with which the production decisions are analyzed.

Biophysical Simulation and Economic Decision Models

One argument for the use of biophysical crop-growth simulation models is to provide yield data in the absence of experimental or farm level data (Musser and Tew 1984; Boggess 1984). Crop-growth simulation models are used for this purpose. Specifically, models are used to simulate the effects of production management decisions on yield response for four crops. The crops modeled are: (1) corn, using the CORNF model by Stapper and Arkin (1980); (2) sorghum, using the SORGF model by Maas and Arkin (1978); (3) wheat, using the TAMW model by Maas and Arkin (1980b); and (4) cotton, using the COTTAM model by Jackson (1987) and Arkin (1987). The production management decisions simulated include planting date and plant population for corn, grain sorghum, wheat, and cotton. Maturity class of corn and grain sorghum is also incorporated. The specific decision levels are given in Appendix 1. Production practices were identified with the help of the Texas Agricultural Extension Service crop specialists and Texas Agricultural Experiment Station crop breeders (Coffman 1987; F. Miller 1987; T. Miller 1987; and Metzer 1987). Planting dates range from early to late plantings and plant populations include three levels: low, medium, and high. Average days to physiological maturity for corn are 121 days for short season, 126 days for medium season, and 129 days for full season. Average days to physiological maturity for grain sorghum are 105 days for short season, 111 days for medium season, and 115 days for full season. These corn maturity class terms are not those commonly used in the area since all of these varieties would fall into the medium-late to late season category. For the convenience of presentation, however, the short, medium, and full classifications are used.

These yield data are used in the economic decision-making model which is a quadratic programming model depicting production conditions including risk. Activities included in the economic model are production activities, machinery operation activities, tractor substitution, input purchases, product sales, expected profit by weather year, and mean expected profit. Optimal activity levels are chosen subject to constraints on available land, rotations, tractor time, operation sequencing, input balance, product balance, expected profit balance by weather year, and mean profit balance. Optimality involves maximizing average returns above variable costs (expected profit) less a risk penalty times the variance of profit. The model allows for selection from among 72 production alternatives for corn (all combinations of 8 planting dates, 3 plant populations, and 3 maturity classes), 81 production alternatives for grain sorghum (combinations of 9 planting dates, 3 plant populations, and 3 maturity classes), 27 production alternatives for wheat (combinations of 9 planting dates and 3 plant populations), and 27 production alternatives for cotton (combinations of 9 planting dates and 3 plant populations).

An overall schematic of the model is given in Figure 3.1. This figure is a simplified version of the economic decision-making model. Generally, each row and column depicts multiple activities and constraints. Corn production activities, for instance, include 72 total variables encompassing the different planting dates, plant populations, and maturity classes. Another example of the simplicity is the tractor time constraints actually include weekly field time constraints. Data incorporated into the model, such as machinery working rates and biophysical simulation yields, are depicted in the figure as a positive or negative sign in the appropriate activity (columns) and constraint (rows).

The decision to engage in a production enterprise is embodied in production activities indexed by crop, planting date, plant population, and maturity class. Under product balance rows for each of the 37 years and each product, the biophysical simulation model yields serve as technical coefficients to be sold at the price under product sales activities. Production activities utilize acreage under the land balance constraint and also require harvesting within operation sequencing constraints. Thus, while several separate operations are included and individually sequenced properly into allowed time periods, Figure 3.1 is simplified to facilitate presentation of the formulation of the model.

Machinery operations require either a small (100 HP) or a large tractor (150 HP) in a given time period thus using tractor time resources. If a specific machinery operation requires a small tractor, the large tractor may be used for that operation through tractor substitution activities, but the small tractor will not substitute for the large tractor. Machinery operations also require the purchase of inputs, definition of input, and enable planned crop rotation through land sequencing rows.

Input purchases and product sales are used to calculate an estimated profit for each of the 37 years of weather conditions simulated. In the mean profit balance row, these profit by year variables are averaged to represent an expected mean profit assuming equally likely weather conditions. The objective function maximizes this expected mean profit less a risk coefficient multiplied by the variance of profit. The expected profit values generated from the decision model include only variable costs.

The Pratt risk aversion coefficient is calculated using the results of McCarl and Bessler (1988). Briefly, a normal distribution of profit is assumed and the risk aversion parameter is calculated by dividing twice the Z value from

	Production Activities: Corn	Production Activities: Sorghum	Production Activities: Wheat	Production Activities: Cotton	Product Sales	Input Purchases	Profit by Year	Mean Profit	Preplanting Operations – Corn After: Corn	Corn After: Sorghum	Corn After: Wheat	Corn After: Cotton	Sorghum After: Corn	Sorghum After: Sorghum	Sorghum After: Wheat	Sorghum After: Cotton	Wheat After: Corn	Wheat After: Sorghum	Wheat After: Wheat	Wheat After: Cotton	Cotton After: Corn	Cotton After: Sorghum	Cotton After: Wheat	Planting Operation: Corn	Planting Operation: Sorghum	Planting Operation: Wheat	Planting Operation: Cotton	Harvesting Operation: Corn	Harvesting Operation: Sorghum	Harvesting Operation: Wheat	Harvesting Operation: Cotton	Tractor Substit	Profit Variance		Right Hand Side
OBJECTIVE FUNCTION								1																									-		MAX
LAND BALANCE	1	1	1	1																														<=	+
LAND SEQUENCING									1				1				1				1							-1						<=	0
										1				1				1				1							-1					<=	0
											1				1				1				1							-1				<=	0
												1				1				1											-1			<=	0
LARGE TRACTOR TIME									+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					1		<=	+
SMALL TRACTOR TIME									+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					-1		<=	+
OPERATION SEQUENCING									-1	-1	-1	-1												1										<=	0
													-1	-1	-1	-1									1									<=	0
																	-1	-1	-1	-1						1								<=	0
																					-1	-1	-1				1							<=	0
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	1																											-1						<=	0
		1																											-1					<=	0
			1																											-1				<=	0
				1																											-1			<=	0
PRODUCT BALANCE	-	-	-	-	+																													<=	0
INPUT PURCHASING						-			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			<=	0
PROFIT BALANCE					+	-	-1																											=	0
MEAN PROFIT							+	-1																										=	0

Figure 3.1. Schematic Depiction of the Blackland Crop Production Management Model.

the normal table corresponding to a chosen level of significance by an estimate of the standard deviation of income. The probability levels underlying the values are varied from risk neutrality (a Z value of 0 is used to depict a decisionmaker who maximizes a level of profit that is 50 percent likely to be met or exceeded) to larger values (a Z value of 1.645 is used to depict a decisionmaker who maximizes a level of profit that is 90 percent likely to be met or exceeded). Thus, the economic model employs a risk coefficient which corresponds to a level of statistical significance representing the probability that at least an expected profit will be received. For a more detailed description of the economic decision-making model see Dillon (1987).

Data Used

Data required by the economic decision-making model are (1) available land, (2) available tractor time, (3) machinery working rates, (4) input requirements and input prices, (5) crop yields, and (6) prices. The farm is assumed to be a commercial operation with 1500 acres.

The available tractor time was calculated assuming the presence of a large (150 HP) and a small (100 HP) tractor. Tractor working time is calculated by multiplying the number of days the tractor could work per week by the number of working hours per day (ten hours per day was assumed). The weekly number of days the tractor could work was developed using a field days criteria function and soil moisture levels from the biophysical simulation models. The field days criteria specify the soil moisture content and rainfall conditions which must be met for a day to be considered a good field day. Three criteria are used to define a workable day (a good field day). (1) If it rains three consecutive days, the third day and the following day are both considered bad field days. (2) If the soil moisture of the top 30 cm (11.81 inches) is 70 percent or greater of soil capacity, the day is considered inappropriate to work. (3) If it rains 0.38 cm (0.15 inches) or more on any given day, that day is not considered a good field day. It is further assumed that labor is only performed on the farm six days out of the week. Therefore, the field days are adjusted by multiplying by 6/7. These rules are modifications of criteria from several studies (Acharya, Hayes, and Brown 1983; Whitson et al. 1981; Elliot, Lembke, and Hunt 1981; Babeir, Calvin, and Marley 1985). The number of field days per week for 37 years are developed and averaged by week.

The above criteria are implemented to determine the number of acceptable days for field work per week (the results appear in Appendix 2). The field time data assumptions were tested to see if they were critical but they turned out not to be (Dillon 1987).

Crop production in the Blackland region may be done via a number of possible operations. The order and time of occurrence of the production operations assumed here are presented in Appendix 3. For agronomic reasons, continuous cotton is not allowed. The four crop yield distributions are assumed constant regardless of the previous crop. All harvesting is assumed to be performed on a custom basis without using any of the farm's own machinery time. However, custom harvest is sequenced with the other operations. The other custom operations conducted aerially (e.g., insecticide applications) are not sequenced and are assumed to be completed in a timely fashion. The timing of activities are influenced by planting date, and it is assumed that each nonplanting operation falls into an operation-dependent 2-week time window relative to planting (as detailed in Appendix 3). Multiple planting dates, however, are allowed. All noncustom operations are subject to available tractor time. Thus, while row cultivation of corn is assumed to occur 3 or 4 weeks after planting, there must be suitable working conditions and tractor time available.

Variable inputs such as fuel, lube, repairs and maintenance, labor, fertilizer, herbicide, and insecticide are required in the completion of machinery and custom operations. The input requirements for each crop are presented in Appendix 4. The prices of inputs assumed in this study are presented in Appendix 5.

Yields and product prices jointly define revenue. The yield results from the biophysical simulators are presented in the next section. The base product prices are $3.16 for a bushel of corn grain, $4.35 for a hundredweight of grain sorghum, $4.31 for a bushel of wheat, $0.7233 per pound of cotton lint, and $69.00 per ton of cottonseed. These prices are calculated by adding the 1986 loan rate and deficiency payment as obtained from Ace Chalapeak of the Bell County Agricultural Stabilization and Conservation Service (ASCS). Note that while the deficiency payment is paid on historical yield and not current yield, the economic model averages simulated yields from 37 crop seasons. Thus, the farmer's historical yield is assumed to equal the average yield under the 37 weather patterns. Cottonseed is not considered a major support commodity and therefore has no loan rate or deficiency payment. Cottonseed price is an assumed market price. All risk incorporated in the economic model is due to yield fluctuations with prices being considered constant.

Because of limited cross-compliance, producers can slowly change their individual base acreages. The question addressed herein regards the crop mix a producer may desire to work towards irrespective of the beginning base acreage. Therefore, to make the analysis more general, base acreage and set-aside considerations are not included in this study. Further, the costs of transitions from a given base acreages to the crop mixes reported here are not considered. Because most producers are in government support programs, decisions should be consequently based on government supported prices. Limited cross-compliance and the fact that most crop producers farm different ASCS units allows for base acreages to be slowly changed.

IV. Results and Analysis of the Study

The simulation models were used to generate data on the effects of planting date, maturity class, and plant population. The results are presented next, followed by the economic results.

Biophysical Simulation Results for Corn, Grain Sorghum, Wheat, and Cotton

Average simulated corn yield across all weather data and management practices is 54 bu/ac (bushels/acre) with a standard deviation of 34 bu/ac and yields ranging from 2 bu/ac to 182 bu/ac. The overall average grain sorghum yield is 32 cwt/ac (hundredweight/acre) with a standard deviation of 22 cwt/ac and a range from 0 cwt/ac to 100 cwt/ac. Average wheat yield is 24 bu/ac with a standard deviation of 6 bu/ac. Wheat yields ranged from a low of 7 bu/ac to a high of 40 bu/ac. Cotton lint produced averaged 241 lbs/ac (pounds/acre) and possessed a standard deviation of 121 lbs/ac. The minimum yield for cotton lint is 63 lbs/ac and the maximum is 756 lbs/ac.

In examining these averages, the reader should keep in mind that extreme cases are included in the computation of these overall yield averages and the yield averages reported throughout this section. For example, late planting of a full season hybrid is included, at equal weight, in the calculations. In normal practice, however, a full season hybrid would not be planted late in the season. Direct calibration of the data set is not possible because of inadequate data which created the need for the use of biophysical simulation. Indirect calibration/validation of the models is beyond the scope of this report but may be found in several studies (Dillon 1987; Maas and Arkin 1978, 1980a, 1980b; Stapper and Arkin 1980; Larsen 1983; Vanderlip and Arkin 1977; Arkin, Vanderlip and Ritchie 1976). Additional descriptive information regarding the particular biophysical simulation models employed may be found in the model documentations previously cited.

Planting Date

In general, simulated yields decrease as planting date is delayed (Table 4.1). Unpublished results of preliminary corn experimental plots in general support these biophysical simulation model results (Cothren 1987). This general downward relationship occurs on average but can differ under specific weather patterns (Figure 4.1). The yields for certain years resulting from biophysical simulation are displayed in Figure 4.1 and are selected to demonstrate the alterations of yield patterns (averaged across all 3 plant populations and all 3 maturity classes where applicable) to planting date as affected by different weather years. The overall averages are also included and represent the mean yield by planting date average across all 37 years (1950-86), all 3 plant populations, and, where applicable, all 3 maturity classes. Later planting dates may yield higher in certain years, but early planting yielded higher on the average. However, all four crops had higher variability in yields (measured by the coefficient of variation) as planting date is delayed (Table 4.1). Wheat and cotton yields have smaller increases in variability than either corn or grain sorghum. The crop yields are significantly different with respect to planting dates (Table 4.1).

Maturity Class

Yield response to maturity class is studied for corn and grain sorghum. On average, corn yield responses are higher for shorter season cultivars while variability is lower (Table 4.2). Again, weather is a determining factor in maturity class response causing specific year results to differ from the average.

Statistical data for yield responses to sorghum cultivar maturity length is also included in Table 4.2. On average, the short season grain sorghum cultivar yielded higher than the medium maturity class, with the full season cultivar yielding slightly less. The medium length cultivar possesses the lowest yields per acre. Weather plays a major role in the determination of final grain sorghum yields with respect to maturity class (Figure 4.2). In terms of variability, short season grain sorghum displayed the least variability while medium and full season varieties exhibited approximately the same variability as measured by coefficient of variation. Significant statistical difference in mean yields is evidenced for maturity class in both corn and grain sorghum. As shown in Table 4.2, each maturity class for corn differed significantly, whereas short and full season sorghum maturity classes significantly differed from medium season but not from each other.

The biophysical results concerning yield response to maturity class differ from agronomically accepted responses of yield to maturity class. The accepted response is that full season hybrids yield higher on average than medium season hybrids which yield higher than short season hybrids. As noted earlier, the overall averages are misleading because practices which are normally not part of a production system are included on these averages (e.g., a full season hybrid planted late). Second, what is denoted as short, medium, and full season maturity classes in this study does not reflect common usage of the terms by Blackland producers. The nomenclature used here is strictly for ease of presentation. The results point out a limitation of the study. The response of yield to different hybrids as given by the crop-growth simulation models is suspect. The conclusions of this study pertaining to maturity classes must be viewed with this limitation in mind.

Population

For all four crops, higher plant densities are accompanied by increased yields (Table 4.3). Again, weather effects should be considered in reviewing these average results (Figure 4.3). The variability of corn yield also increased slightly with higher planting densities. For the

Table 4.1. **Biophysical Crop Simulation Model Results – Summary Statistics for Planting Date.**

CROP[1]	PLANTING DATE[2]	MEAN[3]	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	COEFFICIENT OF VARIATION
CORN	02/14	63.52A	31.85	6.93	165.89	50.14
	02/21	61.46AB	31.87	6.55	163.32	51.85
	02/28	59.24AB	32.37	6.50	171.87	54.64
	03/07	56.63BC	32.19	7.07	168.60	56.84
	03/14	53.17CD	33.14	4.10	182.26	62.31
	03/21	50.83DE	35.15	3.59	179.60	69.15
	03/28	47.47EF	35.44	2.39	182.12	74.66
	04/04	43.06F	35.14	1.92	180.65	81.61
SORGHUM	02/28	40.47A	22.52	1.08	98.01	55.66
	03/07	39.61A	22.44	2.37	98.65	56.65
	03/14	37.14AB	22.24	2.37	98.77	59.89
	03/21	34.67BC	21.81	2.15	99.81	62.91
	03/28	32.19CD	20.87	1.55	85.87	64.84
	04/04	29.13DE	20.69	0.00	85.94	71.04
	04/11	26.65EF	19.82	0.00	80.77	74.39
	04/18	24.18FG	18.78	0.00	80.57	77.69
	04/25	21.68G	17.55	0.00	74.86	80.97
WHEAT	10/03	30.52A	3.91	20.54	40.32	12.83
	10/10	28.91B	4.12	19.40	39.81	14.26
	10/17	27.51C	4.13	18.77	37.40	15.02
	10/24	26.00D	4.10	17.59	36.44	15.77
	10/31	24.80E	4.02	16.35	34.26	16.23
	11/07	23.20F	3.83	14.41	33.03	16.53
	11/14	21.46G	3.87	12.62	31.70	18.03
	11/21	19.55H	4.18	7.72	31.22	21.42
	11/28	17.62I	4.48	6.67	30.29	25.43
COTTON	03/28	281.17A	122.71	85.69	705.99	43.64
	04/04	279.46A	123.15	87.05	698.51	44.06
	04/11	265.35AB	128.11	81.61	687.62	48.28
	04/18	250.61ABC	131.50	78.21	755.64	52.47
	04/25	241.61BCD	121.31	73.45	731.15	50.21
	05/02	227.57CDE	117.93	74.81	659.74	51.82
	05/09	207.75DE	102.36	75.49	507.38	49.27
	05/16	211.37DE	106.67	71.41	574.72	50.46
	05/23	205.82E	108.50	63.25	512.83	52.71

[1] Corn results are in bushels per acre, sorghum in hundred pounds per acre, wheat in bushels per acre, and cotton in pounds per acre.

[2] Planting dates are in month/day. Observations are averaged over all years (1950-1986) under all remaining management practices.

[3] Means followed by the same letter are not significantly different.

Table 4.2. **Biophysical Crop Simulation Model Results – Summary Statistics for Maturity Class.**

CROP[1]	MATURITY CLASS[2]	MEAN[3]	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	COEFFICIENT OF VARIATION
CORN	Short	59.82A	26.38	8.70	138.03	44.10
	Medium	54.48B	33.81	4.23	162.20	62.06
	Full	48.97C	39.75	1.92	182.26	81.16
GRAIN SORGHUM	Short	33.96A	20.35	0.96	82.84	59.94
	Medium	28.35B	20.19	0.00	82.82	71.20
	Full	32.93A	24.08	0.00	99.81	73.13

[1]Corn results are in bushels per acre, sorghum in hundred pounds per acre, wheat in bushels per acre, and cotton in pounds per acre.

[2]Maturity classes are categorized by length of time to maturity and averaged over all years (1950-1986) under all remaining management practices.

[3]Average days to physiological maturity for corn are 121 days for short season, 126 days for medium season, and 129 days for full season. Average days to physiological maturity for grain sorghum are 105 days for short season, 111 days for medium season and 115 days for full season.

[4]Means followed by the same letter are not significantly different.

Table 4.3. **Biophysical Crop Simulation Model Results – Summary Statistics for Plant Population.**

CROP[1]	POPULATION[2]	MEAN[3]	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	COEFFICIENT OF VARIATION
CORN	15000	51.00A	30.27	1.92	149.67	59.35
	19000	54.07A	33.59	1.95	167.80	62.12
	26000	58.19B	37.51	2.23	182.26	64.46
SORGHUM	50000	29.34A	20.39	0.00	89.97	69.50
	57500	31.38B	21.55	0.00	94.21	68.67
	70000	34.52C	22.93	0.00	99.81	66.43
WHEAT	15	67.04A	17.97	19.95	113.71	26.80
	30	74.67B	16.19	32.93	118.71	21.69
	45	77.31C	15.82	37.00	120.65	20.47
COTTON	20000	285.00A	152.74	93.00	856.00	53.59
	42500	351.15B	174.58	130.00	1071.00	49.71
	80000	427.71C	177.56	150.00	1111.00	41.51

[1]Corn results are in bushels per acre, sorghum in hundred pounds per acre, wheat in bushels per acre, and cotton in pounds per acre.

[2]Plant populations are in plants/acre. Observations are averaged over all years (1950-1986) under all remaining management practices.

Means followed by the same letter are not significantly different.

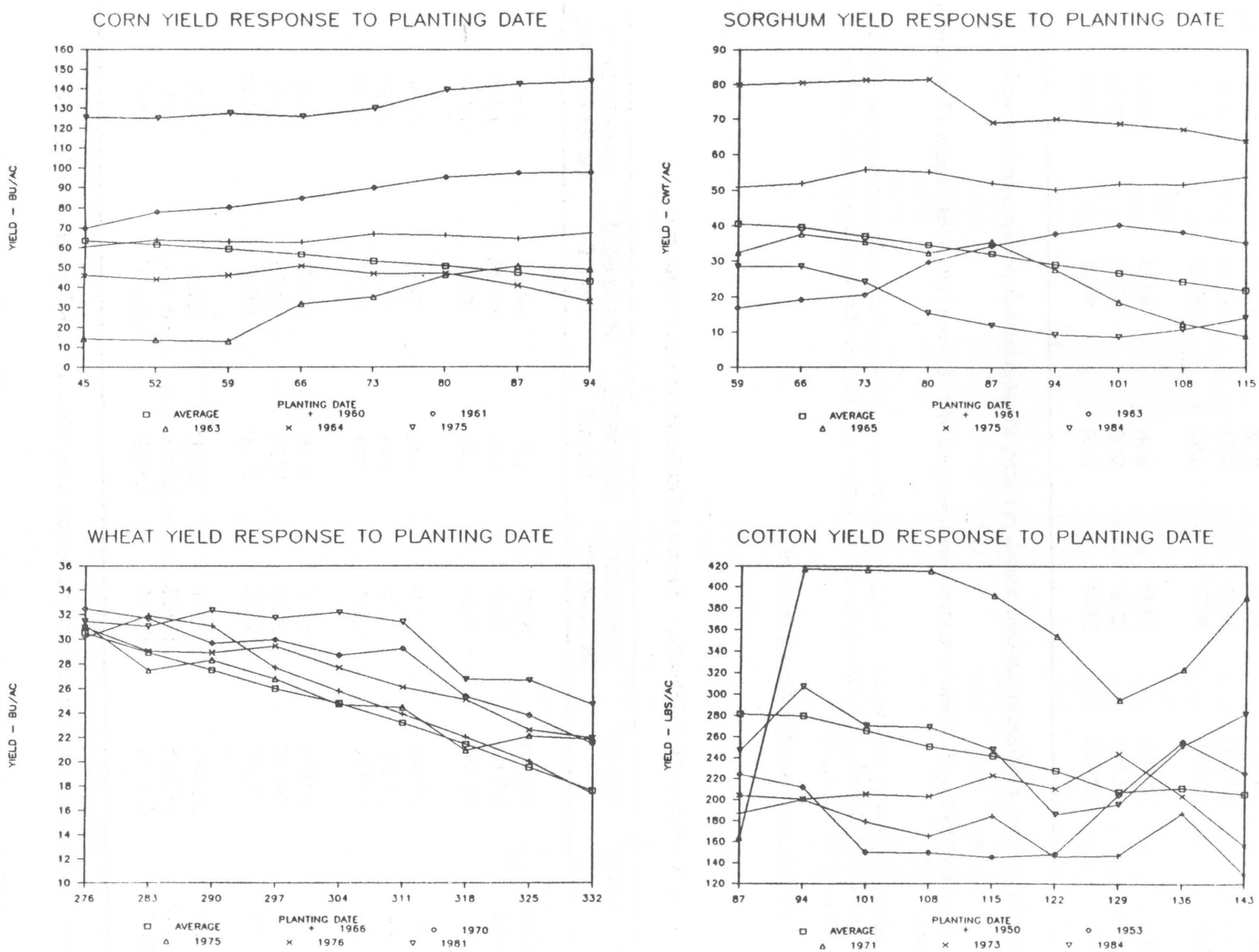


Figure 4.1. Crop Yield Response to Planting Date.

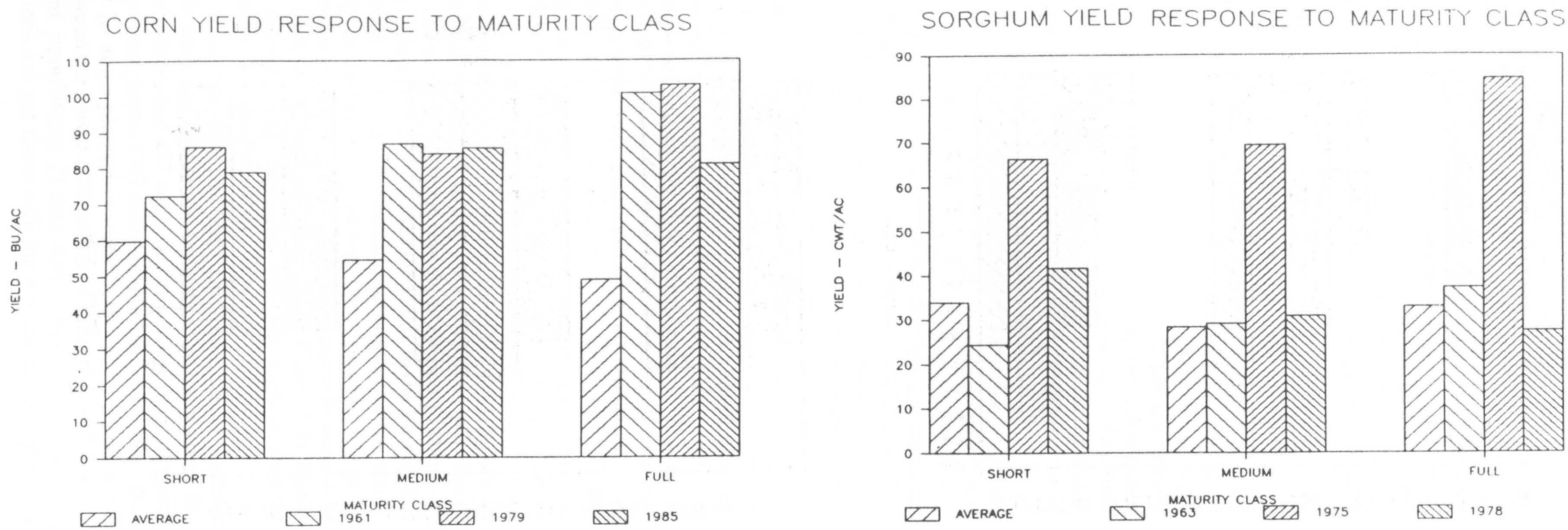
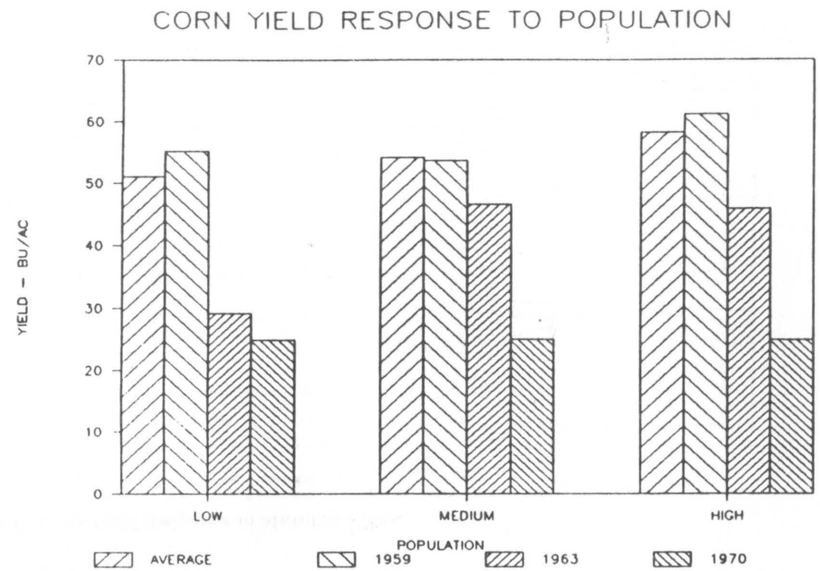
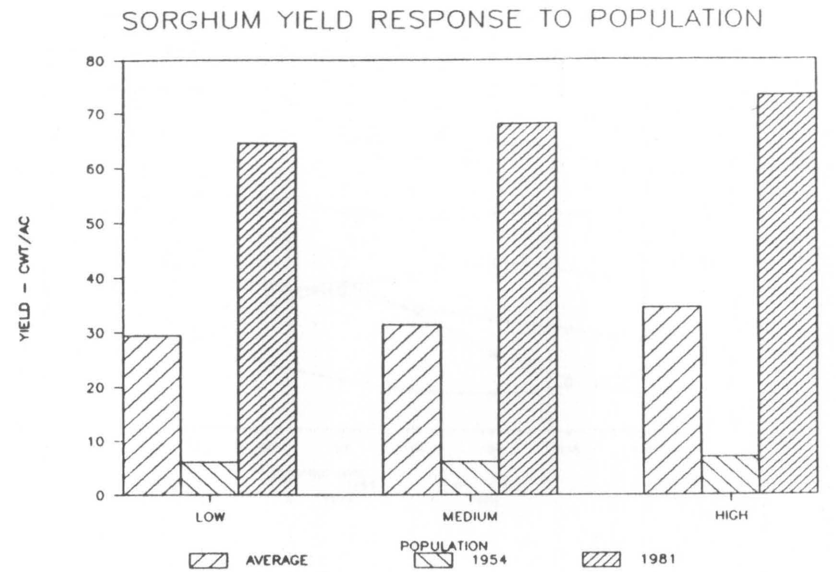
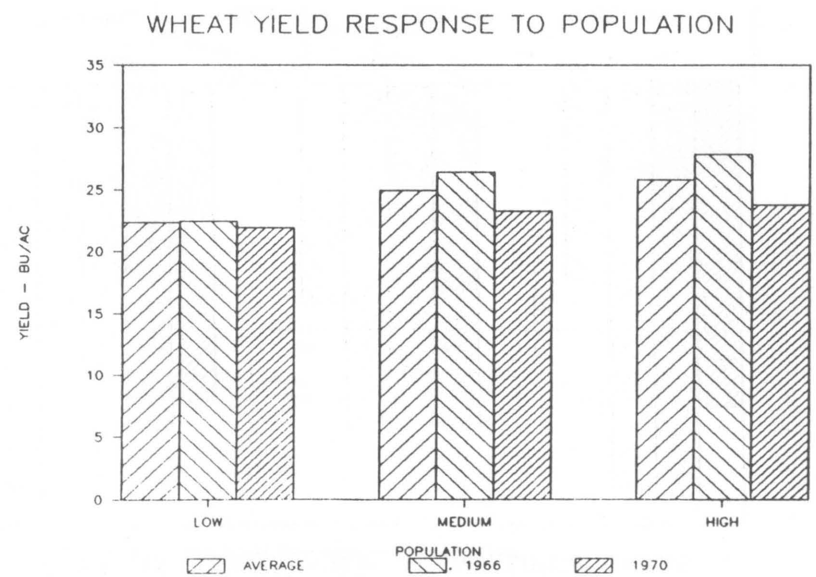


Figure 4.2. Crop Yield Response to Maturity Class.







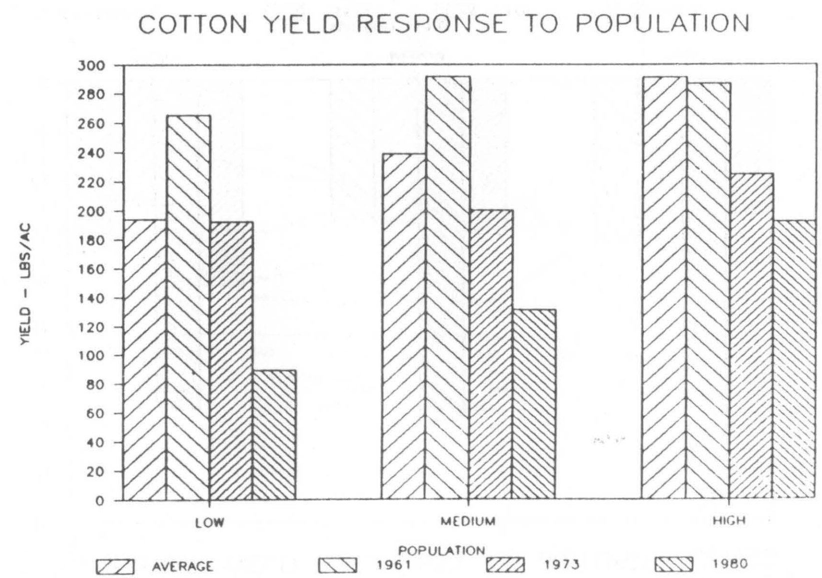


Figure 4.3. Crop Yield Response to Population.

other three crops, yield is less variable as planting density increases. Each crop showed significant yield differences with respect to population.

Economic Analysis

The economic analysis in this study focuses on production management decisions and resultant profit. Two base conditions considered are risk neutrality and low risk aversion. Analysis is also conducted on the effects of differing risk attitudes, corn prices, and corn production management decisions.

Base Conditions

Base conditions include constant economic data (product prices, input prices) and technological production data (crop yields, machinery working rates, etc.). However, two different levels of attitude toward risk are examined for base conditions by altering the risk aversion coefficient. Base conditions include a risk neutral attitude (50 percent certainty of achieving at least the expected profit) and a low risk averse attitude (70 percent certainty of achieving at least the expected profit).

The profit maximizing solution under risk neutrality has a mean profit of $170,103 and a standard deviation of profit of $102,899. Profit ranges between $13,120 and $482,453. The low risk averse solution has a mean profit of $109,742 with a range of $31,697 to $256,502. The standard deviation for profit under the risk averse conditions is $44,244. As expected, the risk averse case has a lower mean profit and standard deviation. Lower variation in profits is obtained at a sacrifice of higher expected profit.

Different production management strategies are employed in risk neutral and risk averse base cases. The optimal crop mix for the risk neutral case is 750 acres of corn and 750 acres of cotton. The land sequencing constraint against continuous cotton limits the solution to 750 acres of cotton. Continuous cotton is agronomically undesirable in terms of adverse effects regarding soil nutrient levels and pest populations. Corn is planted in the two earliest planting periods (with 437 acres of corn planted in week 2/12 - 2/18 and 313 acres of corn planted in week 2/19 - 2/25). Further, the highest corn population and the earliest maturing variety is chosen (Table 4.4). This reflects the highest average yields in the biophysical simulation results. The model elects to produce cotton using the earliest two planting dates (planting 387 acres of cotton in week 3/26 - 4/1 and 363 acres in week 4/2 - 4/8) using the highest plant population (Table 4.4). Again, the management practices with the highest average biophysical model yields are selected.

Under the risk averse base conditions, wheat is added while corn and cotton are reduced (258 acres corn, 785 acres wheat, and 457 acres cotton). Early planted wheat crop is employed (762 acres planted in week 10/1 - 10/7 and 23 acres planted in week 10/8 - 10/14), with a mix between the lowest (692 acres) and the middle (93 acres) plant populations (Table 4.4). These wheat planting periods are not those with the highest average yields or the lowest variances. Yields under these production practices, however, are more negatively correlated with cotton yields across years than other wheat production practices. Thus, these strategies are chosen based on their risk reducing characteristics. The risk averse conditions also exhibit use of the lowest plant population for corn but use of early maturity remains (Table 4.4). The selection of lower corn plant populations is done to lower yield variability. Cotton planting production decisions remained consistent with the risk neutral model.

In both cases, all 1500 acres are planted with the imputed value for an acre of land as $108 under risk neutrality and $22.52 under risk aversion. Most tractor time periods have additional resources available or an imputed value (shadow price) of less then $0.01. Exceptions under risk neutrality are the available large tractor time in weeks 9/10 - 9/16, 9/17 - 9/23, and 9/24 - 9/30. These have imputed values of $46.32, $58.69, and $58.69 respectively. Observation of machinery operations performed indicates that September chiseling operations on both corn and cotton are done during these weeks.

Few tractor allotments are constraining under risk aversion. The imputed values of large tractor time for weeks 5/7 - 5/13 through 5/28 - 6/3 are all $1.01 per hour available. Large and small tractor time both have an imputed value of $55.98 per hour in week 10/1 - 10/7. During the limiting time periods, weeks 5/7 - 5/13 through 5/28 - 6/3, wheat is planted and continuous wheat is tandem disked and chiseled in preparation for renewed planting. Also during this time period, cotton undergoes row cultivation and the wheat crop residue is removed by tandem disking and chiseling to prepare for later cotton planting in the wheat/cotton rotation. The removal of wheat crop residue is apparently a limiting factor in the case of risk aversion as indicated by availability of tractor time during March being a binding constraint. Planting of wheat occurs during week 10/1 - 10/7; therefore, all available small and large tractor time is used to drill wheat during this week.

Whole farm budgets based on the decision model crop mix are calculated for the risk neutral (Table 4.5) and risk averse (Table 4.6) results. In the case of risk neutrality, the expected total farm gross revenue is $363,017, and variable costs total $192,908, giving an expected profit of $170,108. Corn accounts for 48 percent of this profit ($81,914) while cotton contributes 52 percent ($88,194). Expected gross revenue totals $271,233 for the risk averse case with variable costs amounting to $161,426 leading to expected net profit total of $109,807. Corn accounts for 24 percent ($26,132) of the total while wheat contributes 27 percent ($30,226), and cotton 49 percent ($53,449). Expected profit values differ between the quadratic programming and the budget solutions because of rounding.

While corn seed expense represents the highest single preharvest expenditure for corn under risk neutrality, the lower seed requirement of less dense plant populations under risk aversion places corn seed expenses behind balanced fertilizer (10-34-0) and nitrogen costs for preharvest expenditures. Balanced fertilizer, nitrogen,

Table 4.4. Crop Production Management Decisions – Base Agricultural Economic Environment.

CROP	PLANTING DATE	POPULATION	RISK NEUTRAL LEVEL	RISK AVERSE LEVEL
CORN	WEEK 02/12 - 02/18	LOW	0	258
	WEEK 02/12 - 02/18	HIGH	437	0
	WEEK 02/19 - 02/25	HIGH	313	0
WHEAT	WEEK 10/01 - 10/07	LOW	0	668
	WEEK 10/01 - 10/07	MEDIUM	0	94
	WEEK 10/08 - 10/14	LOW	0	23
COTTON	WEEK 03/26 - 04/01	HIGH	387	198
	WEEK 04/02 - 04/08	HIGH	363	259

Table 4.5. Risk Neutral Base Conditions Farm Budget.

Section I. Corn (750 Acres)

	DESCRIPTION	UNIT	PRICE	CORN PER ACRE		CORN ENTERPRISE	
				QUANTITY	TOTAL	QUANTITY	TOTAL
	GROSS REVENUE						
	Corn Grain	BU	3.16	70.72	223.47	53039	167603
1)	**Total Gross Revenue**						167603
	PREHARVEST						
	Fertilizer	LB	0.11	150.00	16.05	112500	12037
	Nitrogen	LB	0.10	165.00	15.68	123750	11756
	Corn Seed	LB	0.97	22.88	22.19	17160	16640
	General Insecticide	GAL	50.10	.19	9.39	140	7045
	General Herbicide	LB	5.94	.75	4.45	562	3339
	Corn Herbicide	LB	4.50	1.00	4.50	750	3375
	Fuel	GAL	0.92	4.08	3.75	3056	2812
	Lube	DOLL	1.00	3.75	.37	281	281
	Repairs & Maint.	DOLL	1.00	2.14	2.14	1605	1605
	Labor	HOUR	5.00	.95	4.77	716	3580
2)	**Total Preharvest Cost**						62473
	HARVEST						
	Custom Harvest-Corn	ACRE	15.00	1.00	15.00	750	11250
	Custom Haul-Corn	BU	0.14	70.72	9.90	53039	7425
3)	**Total Harvest Cost**				24.90		18675
	Interest	DOLL	0.13	46.57	6.05	34927	4540
4)	**Total Variable Cost**				114.25		85689
5)	**Gross Revenue Less Variable Cost**				109.22		81914

Continued on next page.

Table 4.5. Continued.

Section II. Cotton (750 Acres)

DESCRIPTION	UNIT	PRICE	COTTON PER ACRE		COTTON ENTERPRISE	
			QUANTITY	TOTAL	QUANTITY	TOTAL
GROSS REVENUE						
Cotton Lint	LB	0.72	330.86	239.31	248142	179481
Cotton Seed	TON	69.00	0.31	21.24	230	15932
1) **Total Gross Revenue**				260.55		195414
PREHARVEST						
Fertilizer	LB	0.11	100.00	10.70	75000	8025
Nitrogen	LB	0.10	49.00	4.66	36750	3491
Cotton Seed	LB	0.40	23.53	9.41	17647	7058
General Insecticide	GAL	50.10	0.38	18.84	282	14128
Insecticide Applic.	APPL	2.75	2.00	5.50	1500	4125
General Herbicide	LB	5.94	0.75	4.45	562	3339
Cotton Herbicide	LB	6.35	0.75	4.76	562	3571
Fuel	GAL	0.92	6.17	5.68	4630	4260
Lube	DOLL	1.00	5.68	0.57	426	426
Repairs & Maint.	DOLL	1.00	2.90	2.90	2173	2173
Labor	HOUR	5.00	1.36	6.79	1018	5092
2) **Total Preharvest Cost**				74.26		55692
HARVEST						
Desiccant	GAL	9.75	0.50	4.88	375	3656
Desiccant Applic.	ACRE	2.75	1.00	2.75	750	2062
Custom Harvest & Haul - Cotton	LB	0.16	330.86	54.56	248142	40918
3) **Total Harvest Cost**				62.18		46637
Interest	DOLL	0.13	50.15	6.52	37612	4889
4) **Total Variable Cost**						107219
5) **Gross Revenue Less Variable Cost**						88194

Continued on next page.

Table 4.5. Continued.

Section III. Total Farm (1500 Acres)

	DESCRIPTION	UNIT	PRICE	FARM PER ACRE		TOTAL FARM	
				QUANTITY	TOTAL	QUANTITY	TOTAL
	GROSS REVENUE						
	Corn Grain	BU	3.16	35.36	111.74	53039	167603
	Cotton Lint	LB	0.72	165.43	119.65	248142	179481
	Cotton Seed	TON	69.00	0.15	10.62	230	15932
1)	**Total Gross Revenue**				242.01		363017
	PREHARVEST						
	Fertilizer	LB	0.11	125.00	13.38	187500	20062
	Nitrogen	LB	0.10	107.00	10.17	160500	15247
	Corn Seed	LB	0.97	11.44	11.09	17160	16640
	Cotton Seed	LB	0.40	11.76	4.71	17647	7058
	General Insecticide	GAL	50.10	0.28	14.12	422	21173
	Insecticide Applic.	APPL	2.75	1.00	2.75	1500	4125
	General Herbicide	LB	5.94	0.75	4.45	1125	6679
	Corn Herbicide	LB	4.50	0.50	2.25	750	3375
	Cotton Herbicide	LB	6.35	0.38	2.38	562	3571
	Fuel	GAL	0.92	5.12	4.71	7687	7072
	Lube	DOLL	1.00	4.71	0.47	707	707
	Repairs & Maint.	DOLL	1.00	2.52	2.52	3779	3779
	Labor	HOUR	5.00	1.16	5.78	1734	8673
2)	**Total Preharvest Cost**				78.78		118165
	HARVEST						
	Custom Harvest-Corn	ACRE	15.00	0.50	7.50	750	11250
	Custom Haul-Corn	BU	0.14	35.36	4.95	53039	7425
	Desiccant	GAL	9.75	0.25	2.44	375	3656
	Desiccant Applic.	ACRE	2.75	0.50	1.38	750	2062
	Custom Harvest & Haul - Cotton	LB	0.16	165.43	27.28	248142	40918
3)	**Total Harvest Cost**				43.54		65312
	Interest	DOLL	0.13	48.36	6.29	72540	9430
4)	**Total Variable Cost**				128.61		192908
5)	**Gross Revenue Less Variable Cost**				113.41		170108[1]

[1]Differences from the objective function value are because of rounding.

Table 4.6. Risk Averse Base Conditions Farm Budget.

Section I. Corn (258 Acres)

	DESCRIPTION	UNIT	PRICE	CORN PER ACRE		CORN ENTERPRISE	
				QUANTITY	TOTAL	QUANTITY	TOTAL
	GROSS REVENUE						
	Corn Grain	BU	3.16	64.98	205.35	16765	52980
1)	**Total Gross Revenue**				205.35		52980
	PREHARVEST						
	Fertilizer	LB	0.11	150.00	16.05	38700	4140
	Nitrogen	LB	0.10	165.00	15.68	42570	4044
	Corn Seed	LB	0.97	13.20	12.80	3405	3302
	General Insecticide	GAL	50.10	0.19	9.39	48	2423
	General Herbicide	LB	5.94	0.75	4.45	193	1148
	Corn Herbicide	LB	4.50	1.00	4.50	258	1161
	Fuel	GAL	0.92	4.08	3.75	1051	967
	Lube	DOLL	1.00	3.75	0.37	967	96
	Repairs & Maint.	DOLL	1.00	2.14	2.14	552	552
	Labor	HOUR	5.00	0.95	4.77	246	1231
2)	**Total Preharvest Cost**				73.91		19068
	HARVEST						
	Custom Harvest–Corn	ACRE	15.00	1.00	15.00	258	3870
	Custom Haul–Corn	BU	0.14	64.98	9.10	16765	2347
	Total Harvest Cost				24.10		6217
	Interest	DOLL	0.13	46.57	6.05	12015	1561
4)	**Total Variable Cost**				104.06		26848
5)	**Gross Revenue Less Variable Cost**				101.29		26132

Continued on next page.

Table 4.6. Continued.

Section II. Wheat (785 Acres)

	DESCRIPTION	UNIT	PRICE	WHEAT PER ACRE		WHEAT ENTERPRISE	
				QUANTITY	TOTAL	QUANTITY	TOTAL
	GROSS REVENUE						
	Wheat Grain	BU	4.31	29.27	126.15	22994	99106
1)	**Total Gross Revenue**				126.15		99106
	PREHARVEST						
	Fertilizer	LB	0.11	100.00	10.70	78500	8399
	Nitrogen	LB	0.10	61.00	5.80	47885	4549
	Wheat Seed	LB	0.19	58.71	11.27	46152	8861
	Custom Insecticide	GAL	248.40	0.03	7.70	48	12089
	Insecticide Applic.	APPL	2.75	1.00	2.75	1570	4317
	Wheat Herbicide – 1	LB	12.50	0.13	1.56	98	1226
	Wheat Herbicide – 2	GAL	15.22	0.33	5.02	259	3942
	Herbicide Applic.	APPL	2.75	1.00	2.75	785	2158
	Fuel	GAL	0.92	3.57	3.28	2784	2561
	Lube	DOLL	1.00	3.28	0.33	256	256
	Repairs & Maint.	DOLL	1.00	1.47	1.47	1147	1147
	Labor	HOUR	5.00	0.69	3.44	538	2690
2)	**Total Preharvest Cost**				56.07		52200
	HARVEST						
	Custom Harvest–Wheat	ACRE	12.00	1.00	12.00	785	9420
	Custom Haul–Wheat	BU	0.12	29.27	3.51	22994	2759
3)	**Total Harvest Cost**				15.51		12179
	Interest	DOLL	0.13	43.54	5.66	34610	4499
4)	**Total Variable Cost**				77.25		68879
5)	**Gross Revenue Less Variable Cost**				48.91		30226

Continued on next page.

Table 4.6. Continued.

Section III. Cotton (457 Acres)

DESCRIPTION	UNIT	PRICE	COTTON PER ACRE		COTTON ENTERPRISE	
			QUANTITY	TOTAL	QUANTITY	TOTAL
GROSS REVENUE						
Cotton Lint	LB	0.72	331.04	239.44	151298	109434
Cotton Seed	TON	69.00	0.31	21.25	140	9713
1) Total Gross Revenue				260.70		119147
PREHARVEST						
Fertilizer	LB	0.11	100.00	10.70	45700	4889
Nitrogen	LB	0.10	49.00	4.66	22393	2127
Cotton Seed	LB	0.40	23.53	9.41	10752	4301
General Insecticide	GAL	50.10	0.38	18.84	171	8608
Insecticide Applic.	APPL	2.75	2.00	5.50	914	2513
General Herbicide	LB	5.94	0.75	4.45	342	2034
Cotton Herbicide	LB	6.35	0.75	4.76	342	2176
Fuel	GAL	0.92	6.51	5.99	2975	2737
Lube	DOLL	1.00	5.99	0.60	273	273
Repairs & Maint.	DOLL	1.00	3.04	3.04	1389	1389
Labor	HOUR	5.00	1.37	6.87	627	3139
2) Total Preharvest Cost				74.82		34192
HARVEST						
Desiccant	GAL	9.75	0.50	4.88	228	227
Desiccant Applic.	ACRE	2.75	1.00	2.75	457	1256
Custom Harvest & Haul – Cotton	LB	0.16	331.04	54.59	151298	24949
3) Total Harvest Cost				62.21		28433
Interest	DOLL	0.13	52.87	6.87	23631	3072
4) Total Variable Cost				143.19		65698
5) Gross Revenue Less Variable Cost				116.79		53449

Continued on next page.

Table 4.6. Continued

Section IV. Total Farm (1500 Acres)

DESCRIPTION	UNIT	PRICE	FARM PER ACRE		TOTAL FARM	
			QUANTITY	TOTAL	QUANTITY	TOTAL
GROSS REVENUE						
Corn Grain	BU	3.16	11.18	35.32	16765	52980
Wheat Grain	BU	4.31	15.51	66.86	22994	99106
Cotton Lint	LB	0.72	98.65	71.35	151298	109434
Cotton Seed	TON	69.00	0.09	6.33	140	9713
1) Total Gross Revenue				179.87		271233
PREHARVEST						
Fertilizer	LB	0.11	108.60	11.62	162900	17430
Nitrogen	LB	0.10	75.31	7.15	112848	10720
Corn Seed	LB	0.97	2.27	2.20	3405	3302
Wheat Seed	LB	0.19	31.12	5.97	46152	8861
Cotton Seed	LB	0.40	7.01	2.80	10752	4301
General Insecticide	GAL	50.10	0.14	7.23	220	11032
Custom InsecticidE	GAL	248.40	0.02	4.08	48	12089
Insecticide Applic.	APPL	2.75	1.13	3.10	2484	6831
General Herbicide	LB	5.94	0.35	2.09	536	3183
Corn Herbicide	LB	4.50	0.17	0.77	258	1161
Wheat Herbicide – 1	LB	12.50	0.07	0.83	98	1226
Wheat HerbicidE – 2	GAL	15.22	0.17	2.66	259	3942
Cotton Herbicide	LB	6.35	0.22	1.42	342	2176
Herbicide Applic.	APPL	2.75	0.53	1.46	785	2158
Fuel	GAL	0.92	4.53	4.17	6811	6266
Lube	DOLL	1.00	4.17	0.42	626	626
Repairs & Maint.	DOLL	1.00	2.05	2.05	3090	3090
Labor	HOUR	5.00	0.94	4.69	1412	7061
2) Total Preharvest Cost				64.73		105462
HARVEST						
Custom Harvest-Corn	ACRE	15.00	0.17	2.58	258	3870
Custom Haul-Corn	BU	0.14	11.18	1.56	16765	2347
Custom Harvest-Wheat	ACRE	12.00	0.53	6.36	785	9420
Custom Haul-Wheat	BU	0.12	15.51	1.86	22994	2759
Desiccant	GAL	9.75	0.15	1.45	228	2227
Desiccant Applic.	ACRE	2.75	0.30	0.82	457	1256
Custom Harvest & Haul – Cotton	LB	0.16	98.65	16.27	151298	24949
3) Total Harvest Cost				30.91		46830
Interest	DOLL	0.13	46.84	6.09	70256	9133
4) Total Variable Cost				101.72		161426
5) Gross Revenue Less Variable Cost				78.15		109807[1]

[1]Differences from the objective function value are due to rounding.

and seed expenditures represent a significant portion of the total preharvest costs for all three enterprises. Insecticide costs are the predominant preharvest expenses for both wheat and cotton. Cotton harvesting and hauling costs represent about 44 percent of total variable costs of cotton production.

Seed costs are usually the major single preharvest expense for wheat production. The high insecticide costs result from the assumption of applying insecticide twice for wheat production. Because the biophysical simulation models assume optimal pest control, the assumption of two insecticide applications is made. Analysis assuming only one insecticide application on wheat showed similar results. The risk neutral case results remained identical. The low risk averse case changed only slightly with wheat increasing from 785 to 795 acres replacing 10 acres of cotton and the mean profit rising from $109,807 to $117,219. It should be noted that the results presented in the remainder of this report are based on two insecticide applications on wheat.

Risk Analysis

An important issue is the effect of different risk attitudes on expected profit, standard deviation of profit, and production decisions. Risk analysis is conducted by systematically altering the risk aversion parameter in the objective function and solving the model.

The economic model is solved for significance levels of 50 percent (risk neutral) to 90 percent confidence in 5 percent increments. The resultant expected profits, standard deviations, and crop acreages are given in Table 4.7. A summary of the crop production management decisions for the different risk aversion levels is found in Table 4.8. As risk aversion increases from 50 percent to 55 percent, the risk neutral cropping strategy remains optimal until the risk significance equals 60 percent. At this point, wheat enters the solution at approximately 23 percent of total crop acreage, replacing corn which drops to about 27 percent of the acreage while cotton remains unchanged. Beyond the 60 percent risk level, wheat acreage replaces both cotton and corn as risk aversion increases. Cotton acreage remains higher than the corn acreage from the 60 percent to a 90 percent risk significance level. The percentage of corn acreage planted continuously decreases with the exception of a slight increase of less than 1 percent between the 70 and 75 risk significance levels. The range of risk significance levels used is adequate in that the final risk significance level results in the planting of only 1364 of the available 1500 acres. Risk aversion of this level or higher are met by an actual reduction in cropland being planted.

The effects of risk in terms of variance and expected profit is given in Figure 4.4 in the form of an expected profit-variance (E-V) frontier. This shows that increasing expected profit requires bearing increasing risk. The relationship is relatively linear from expected profit levels of $74,697 to $117,169. After $117,169, the relationship is noticeably more nonlinear with variance increasing at an increasing rate. As expected, the maximum profit achieved at risk neutrality is associated with the greatest profit variance (Figure 4.4).

Analysis of the Corn Production Enterprise – Corn Price

In order to further analyze the role of corn, the effects of changing corn prices on profit and production decisions are studied. This is done by solving under several alternative corn prices. Results are generated for the three risk aversion levels of 50 percent (risk neutral), 70 percent (low risk aversion), and 90 percent (high risk aversion) under selected corn prices from -20% to +50% of base price ($3.16/bu) or $2.53/bu to $4.74/bu. The other crop prices remain fixed. It should be noted that corn price and sorghum grain price especially move together; however, in order to develop an estimated firm-level supply function for corn, only the price of corn is varied.

The effects of changes in the corn price are illustrated in Table 4.9. Mean profit and standard deviation increase as the corn price increases. These increases are more dramatic in the risk neutral case than the risk averse cases. This is also more pronounced in low risk aversion than high risk aversion cases. Below a corn price of $2.84/bu (10 percent decrease in base price) under risk neutrality, corn does not enter the solution. In either risk averse case, the lowering of corn price by 20 percent to $2.53/bu results in no corn production. The production management decisions are more stable under corn price changes at higher levels of risk aversion (Table 4.10).

The optimal crop mixes developed for the various corn prices suggest a close substitutability between corn and grain sorghum. Under risk neutral conditions, a 10 percent corn price decrease to $2.84/bu is accompanied by replacement of corn with grain sorghum. Only in the case of a 10 percent decrease in corn price under high risk aversion do both corn (87 acres) and grain sorghum (39 acres) enter the solution simultaneously. Wheat is not present in the risk neutral solution regardless of the corn price level. Under low and high risk aversion corn price analysis, wheat is always present, ranging 51 percent to 55 percent and 72 percent to 76 percent of the planted acreage for low and high risk aversion, respectively. Cotton varied most under risk neutrality (21 percent to 50 percent of the planted acreage) and least under high risk (13 percent to 18 percent) with low risk aversion ranging from 22 percent to 35 percent of the total acreage planted. Risk considerations interactively influence the selection of production management decisions with corn price conditions.

In Figure 4.5, a graph of the inverse firm level supply curve, with the price of corn on the horizontal axis, presents each of the three risk levels given the base prices for remaining crops. Because of the acreage responses, the corn supply response to price changes under risk neutrality is more pronounced than for the risk averse cases. The risk averse supply curves are relatively constant after a corn price of $3.16 per bushel. For all three risk levels, the corn supply curve is less sensitive at higher corn prices than lower ones.

Table 4.7. Risk Study Analysis – General Results.

RISK LEVEL	EXPECTED PROFIT	STANDARD DEVIATION OF PROFIT	PLANTED ACREAGE CORN	GRAIN SORGHUM	WHEAT	COTTON	TOTAL LAND USED
	------- Dollars -------		----------	----------	Acres	----------	----------
50	170103	102899	750	0	0	750	1500
55	163986	89062	750	0	0	750	1500
60	142800	68669	400	0	350	750	1500
65	120655	51942	303	0	645	552	1500
70	109742	44244	258	0	785	457	1500
75	102652	40231	265	0	845	389	1500
80	91951	34631	211	0	958	331	1500
85	84203	30860	181	0	1040	279	1500
90	74697	26720	159	0	976	229	1364

Table 4.8. Production Management Decisions – Risk Study Results.

TOTAL ACREAGE FOR CLASSIFICATION	RISK SIGNIFICANCE LEVEL 50[1]	55	60	65	70	75	80	85	90
CORN TOTAL	750	750	400	303	258	265	211	181	159
Plant Week 02/12-02/18	437	370	400	303	258	265	211	181	159
Plant Week 02/19-02/25	313	380	0	0	0	0	0	0	0
Low Population	0	487	400	303	258	265	211	181	159
Medium Population	0	263	0	0	0	0	0	0	0
High Population	750	0	0	0	0	0	0	0	0
Short Season	750	750	400	303	258	265	211	181	159
SORGHUM TOTAL	0	0	0	0	0	0	0	0	0
WHEAT TOTAL	0	0	350	645	785	845	958	1040	976
Plant Week 10/01-10/07	0	0	350	645	762	762	762	762	739
Plant Week 10/08-10/14	0	0	0	0	23	83	0	0	0
Plant Week 10/15-10/21	0	0	0	0	0	0	132	108	145
Plant Week 10/22-10/28	0	0	0	0	0	0	64	170	92
Low Population	0	0	350	645	691	223	196	278	237
Medium Population	0	0	0	0	93	622	762	762	739
COTTON TOTAL	750	750	750	552	457	389	331	279	229
Plant Week 03/26-04/01	387	320	350	249	198	184	162	128	96
Plant Week 04/02-04/08	363	430	400	303	259	205	169	151	133
High Population	750	750	750	552	457	389	331	279	229

[1]These numbers stand for the income confidence interval level that goes into setting the risk aversion parameter. Namely, the risk aversion parameter is set so that the marginal contribution to income in the EV model is the same as that in a mean minus standard error model with a risk aversion parameter which equals the normal Z value which yields the specified confidence interval. McCarl and Bessler (1988) provide details.

Table 4.9. Corn Price Study Analysis – General Results.

Section I. Risk Neutral Conditions

CORN PRICE	EXPECTED PROFIT	STANDARD DEVIATION OF PROFIT	PLANTED ACREAGE CORN	GRAIN SORGHUM	WHEAT	COTTON	TOTAL LAND USED
	Dollars		Acres				
2.53	159320	96959	0	750	0	750	1500
2.84	159320	96959	0	750	0	750	1500
3.16	170103	102899	750	0	0	750	1500
3.48	187739	116604	959	0	0	541	1500
3.79	211042	131395	1099	0	0	400	1500
4.11	235426	141151	1100	0	0	399	1500
4.42	260865	156853	1191	0	0	308	1500
4.74	286882	167401	1191	0	0	308	1500

Section II. Low Risk Averse Conditions

CORN PRICE	EXPECTED PROFIT	STANDARD DEVIATION OF PROFIT	PLANTED ACREAGE CORN	GRAIN SORGHUM	WHEAT	COTTON	TOTAL LAND USED
	Dollars		Acres				
2.53	106569	44694	0	150	818	532	1500
2.84	106233	43803	208	0	785	506	1500
3.16	109742	44244	258	0	785	457	1500
3.48	115946	46070	301	0	774	425	1500
3.79	123586	48498	350	0	762	388	1500
4.11	130899	50562	369	0	762	369	1500
4.42	139228	53130	392	0	764	344	1500
4.74	146743	55232	403	0	779	318	1500

Section III. High Risk Averse Conditions

CORN PRICE	EXPECTED PROFIT	STANDARD DEVIATION OF PROFIT	PLANTED ACREAGE CORN	GRAIN SORGHUM	WHEAT	COTTON	TOTAL LAND USED
	Dollars		Acres				
2.53	71618	25973	0	89	1094	254	1438
2.84	72182	26150	87	39	1038	246	1409
3.16	74697	26720	159	0	976	229	1364
3.48	77507	27323	181	0	937	206	1325
3.79	79534	27595	181	0	916	195	1293
4.11	81910	28035	181	0	912	184	1278
4.42	84378	28533	182	0	908	173	1264
4.74	86977	29102	184	0	903	161	1248

Table 4.10. Production Management Decisions – Corn Price Study Results.

Section I. Risk Neutral Conditions

TOTAL ACREAGE FOR CLASSIFICATION	CORN PRICE – DOLLARS/BUSHEL						
	2.84 & 2.53	3.16	3.48	3.79	4.11	4.42	4.74
CORN TOTAL	0	750	959	1099	1100	1191	1191
Plant Week 02/12 - 02/18	0	437	536	539	539	365	365
Plant Week 02/19 - 02/25	0	313	423	424	424	423	423
Plant Week 02/26 - 03/04	0	0	0	136	137	403	403
High Population	0	750	959	1099	1100	1191	1191
Short Season	0	750	959	1099	1100	1191	1191
SORGHUM TOTAL	750	0	0	0	0	0	0
Plant Week 02/26 - 03/04	436	0	0	0	0	0	0
Plant Week 03/05 - 03/11	314	0	0	0	0	0	0
High Population	750	0	0	0	0	0	0
Short Season	750	0	0	0	0	0	0
WHEAT TOTAL	0	0	0	0	0	0	0
COTTON TOTAL	750	750	541	400	399	308	308
Plant Week 03/26 - 04/01	387	387	277	142	139	86	86
Plant Week 04/08	363	363	264	258	260	222	222
High Population	750	750	541	400	399	308	308

Continued on next page.

Table 4.10. Continued.

Section II. Low Risk Averse Conditions

TOTAL ACREAGE FOR CLASSIFICATION	CORN PRICE – DOLLARS/BUSHEL							
	2.53	2.84	3.16	3.48	3.79	4.11	4.42	4.74
CORN TOTAL	0	208	258	301	350	369	392	403
Plant Week 02/12 - 02/18	0	208	258	301	350	369	391	402
Low Population	0	208	258	301	350	369	392	403
Short Season	0	208	258	301	350	369	392	402
SORGHUM TOTAL	150	0	0	0	0	0	0	0
Plant Week 02/26 - 03/04	150	0	0	0	0	0	0	0
High Population	150	0	0	0	0	0	0	0
Short Season	150	0	0	0	0	0	0	0
WHEAT TOTAL	817	786	785	774	762	762	764	779
Plant Week 10/01 - 10/07	730	762	762	762	762	762	762	762
Plant Week 10/08 - 10/14	0	24	23	12	0	0	2	17
Plant Week 10/15 - 10/21	63	0	0	0	0	0	0	0
Plant Week 10/22 - 10/28	24	0	0	0	0	0	0	0
Low Population	479	669	692	618	364	116	2	17
Medium Population	338	117	93	156	398	646	762	762
COTTON TOTAL	532	506	457	425	388	369	344	318
Plant Week 03/26 - 04/01	357	297	198	124	87	87	87	83
Plant Week 04/02 - 04/08	174	208	259	301	301	281	257	235
High Population	532	506	457	425	388	369	344	318

Continued on next page.

Table 4.10. Continued.

Section III. High Risk Averse

TOTAL ACREAGE FOR CLASSIFICATION	CORN PRICE – DOLLARS/BUSHEL							
	2.53	2.84	3.16	3.48	3.79	4.11	4.42	4.74
CORN TOTAL	0	87	159	181	181	181	182	184
Plant Week 02/12 - 02/18	0	87	159	181	181	181	182	184
Low Population	0	87	159	181	181	181	182	184
Short Season	0	86	159	181	181	181	182	184
SORGHUM TOTAL	89	39	0	0	0	0	0	0
Plant Week 02/26 - 03/04	89	39	0	0	0	0	0	0
High Population	89	39	0	0	0	0	0	0
Short Season	89	39	0	0	0	0	0	0
WHEAT TOTAL	1094	1038	976	938	916	912	908	904
Plant Week 10/01 - 10/07	670	705	739	762	762	762	762	762
Plant Week 10/08 - 10/14	0	0	0	0	0	0	2	6
Plant Week 10/15 - 10/21	163	163	145	151	153	150	144	136
Plant Week 10/22 - 10/28	261	170	92	25	1	0	0	0
Low Population	424	333	237	176	154	150	146	142
Medium Population	670	705	739	762	762	762	762	762
COTTON TOTAL	254	246	229	206	195	184	173	161
Plant Week 03/26 - 04/01	130	121	96	75	66	53	40	26
Plant Week 04/02 - 04/08	124	125	133	131	129	131	133	135
High Population	254	246	229	206	195	184	173	161

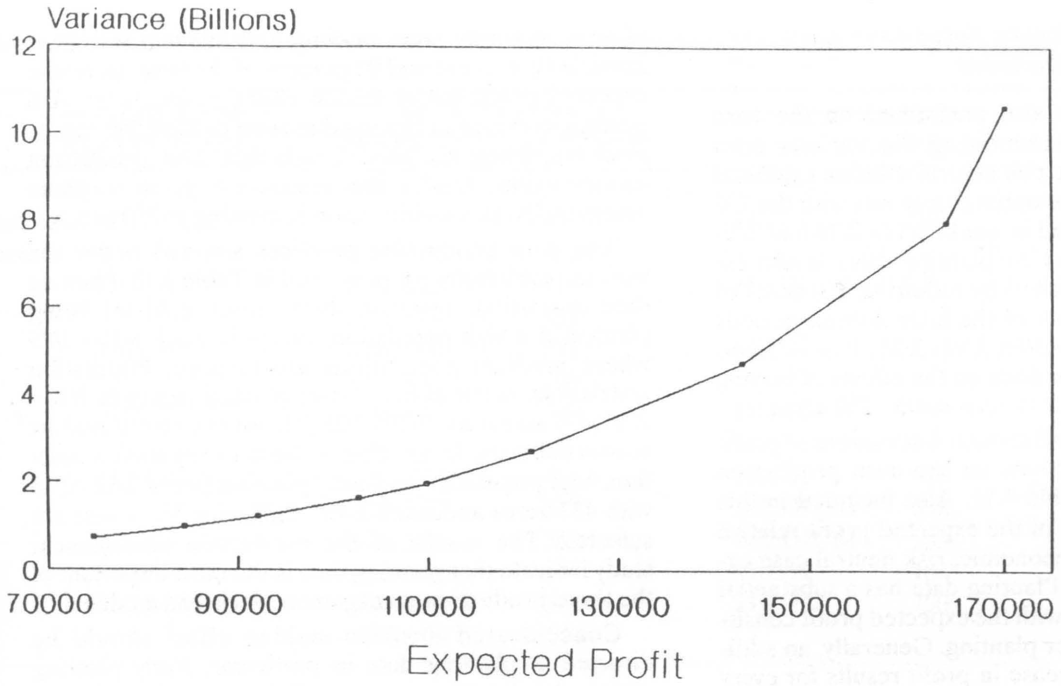


Figure 4.4. Relationship Between the Variance of Profit and Expected Profit (EV).

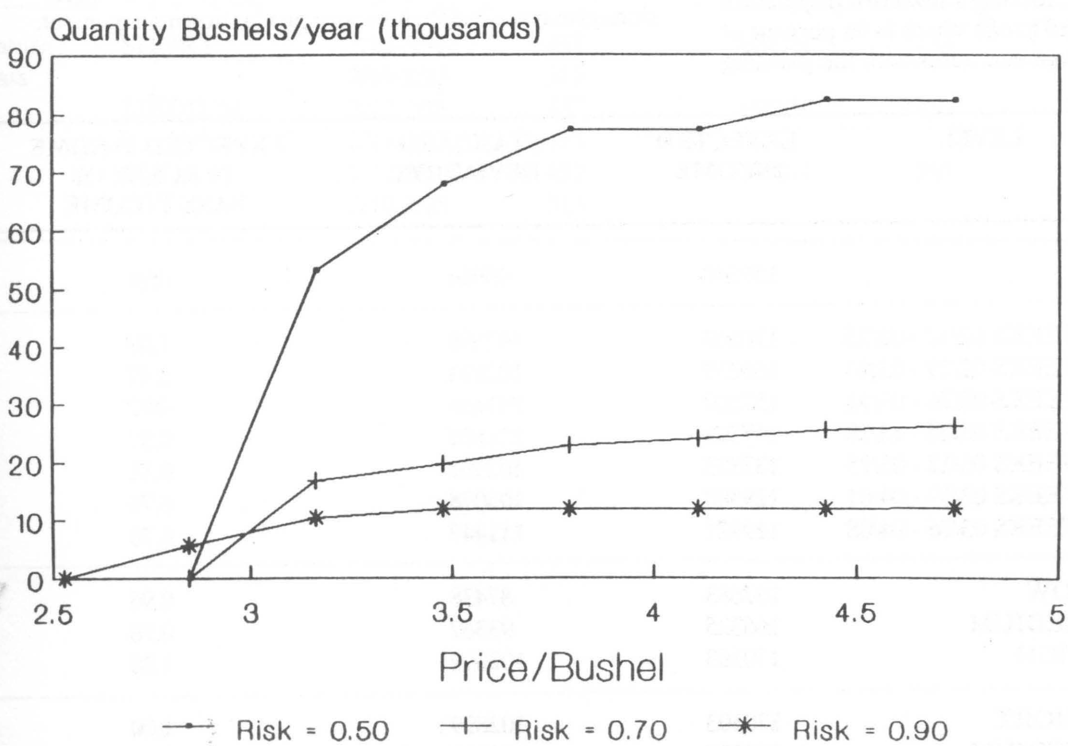


Figure 4.5. Inverse Supply for Corn at the Firm Level.

Analysis of the Corn Production Enterprise – Corn Production Management Decisions

Economic analysis is also performed on the corn production enterprise examining the various corn production practices. The risk neutral solution exhibited half corn and cotton as the optimal crop mix with the 750 acres of corn being planted in weeks 2/12 - 2/18 and 2/19 - 2/25. The sensitivity to other planting dates is also examined. This is accomplished by requiring 750 acres of corn to be planted in each of the later 2-week periods (2/19 - 3/4, 2/26 - 3/11, 3/5 - 3/18, 3/12 - 3/25, 3/19 - 4/1, and 3/26 - 4/8). Analysis is also done on the effects of varying plant populations or maturity class on the 750 acres.

The expected profits and standard deviations of profit under the various restrictions on the corn production practices are given in Table 4.11. Also included in this table are the percentages of the expected profit relative to the unrestricted base economic, risk neutral case expected profit ($170,103). Planting date has a substantial effect on expected profit, with the expected profit consistently decreasing with later planting. Generally, an additional 5 to 6 percent decrease in profit results for every week later planting occurs. With lower corn plant populations, expected profit decreases only slightly. High population is the optimal management practice under the base economic condition. Forcing the model to plant at the medium population gives an expected profit which is 98 percent of the profit derived from planting at the high population. Furthermore, forcing a low corn population level results in an expected profit which is 96 percent of the optimal income. Income decreases with the planting of later maturing corn medium and full season classes result in 95 percent and 90 percent of the base economic expected profit (short season class), respectively. A 6 percent decrease in expected income to $159,340 results from restricting the model such that corn production cannot occur. Under this restriction, grain sorghum enters at 750 acres with cotton remaining at 750 acres.

The corn production practices selected under the various restrictions are presented in Table 4.12. Planting date restrictions result in short season cultivars being planted at a high population, except in week 3/19 - 3/25 where medium populations are favored. Population restrictions result in corn being planted in weeks 2/12 - 2/18 (437 acres) and 2/19 - 2/25 (313 acres), as well as short season cultivars. Regardless of the maturity class restriction, high population and early planting (week 2/12 - 2/18 with 437 acres and week 2/19 - 2/25 with 313 acres) are selected. The results of the production management study indicate that planting date is the most important of the three production management decisions modeled.

Concentrated decision-making effort should be directed at planting date in particular. Early planting seems advantageous economically in terms of production on the average, but the risk of early freezing and adverse weather should be considered. A high plant population is apparently a desirable condition for profit maximization but can be lowered to possibly counteract risk effects. More research regarding corn yield responses to production practices is needed, but initially the above suggestions give some insight into corn production management.

PRODUCTION PRACTICE	LEVEL	EXPECTED INCOME	STANDARD DEVIATION	EXPECTED INCOME PERCENT OF BASE INCOME
No Corn		159340	96966	0.94
Planting Date	WEEKS 02/12 - 02/25	170103	102899	1.00
Planting Date	WEEKS 02/19 - 03/04	165259	102131	0.97
Planting Date	WEEKS 02/26 - 03/11	157302	101059	0.92
Planting Date	WEEKS 03/05 - 03/18	147701	101606	0.87
Planting Date	WEEKS 03/12 - 03/25	137813	102391	0.81
Planting Date	WEEKS 03/19 - 04/01	129500	104078	0.76
Planting Date	WEEKS 03/26 - 04/08	119921	111447	0.70
Population	LOW	162683	87438	0.96
Population	MEDIUM	166325	93367	0.98
Population	HIGH	170103	102899	1.00
Maturity Class	SHORT	170103	102899	1.00
Maturity Class	MEDIUM	162220	117397	0.95
Maturity Class	FULL	152498	132883	0.90

Table 4.11. Corn Production Management Practices Study Analysis -- General Results.

Table 4.12. Production Management Decisions – Corn Production Management Practices Study Results.

PRODUCTION RESTRICTION		PLANTING DATE WEEK	PLANTING DATE ACREAGE	POPULATION CLASS	POPULATION ACREAGE	MATURITY CLASS CLASS	MATURITY CLASS ACREAGE
Planting Weeks	02/12-02/25	2/12-2/18	437	HIGH	750	SHORT	750
		2/19-2/25	313				
	02/19-03/04	2/19-2/25	513	HIGH	750	SHORT	750
		2/26-3/04	237				
	02/26-03/11	2/26-3/04	541	HIGH	750	SHORT	750
		3/05-3/11	209				
	03/05-03/18	3/05-3/11	470	HIGH	750	SHORT	750
		3/12-3/18	280				
	03/12-03/25	3/12-3/18	418	HIGH	418	SHORT	750
		3/19-3/25	332	MEDIUM	332		
	03/19-04/01	3/19-3/25	569	MEDIUM	569	SHORT	750
		3/26-4/01	181	HIGH	181		
	03/26-04/08	3/26-4/01	574	HIGH	750	SHORT	750
		4/02-4/08	176				
Population	LOW	2/12-2/18	437	LOW	750	SHORT	750
		2/19-2/25	313				
	MEDIUM	2/12-2/18	437	MEDIUM	750	SHORT	750
		2/19-2/25	313				
	HIGH	2/12-2/18	437	HIGH	750	SHORT	750
		2/19-2/25	313				
Maturity Class	SHORT	2/12-2/18	437	HIGH	750	SHORT	750
		2/19-2/25	313				
	MEDIUM	2/12-2/18	437	HIGH	750	MEDIUM	750
		2/19-2/25	313				
	FULL	2/12-2/18	437	HIGH	750	FULL	750
		2/19-2/25	313				

V. Concluding Comments

This study lends itself to several areas of concluding comments. First, comments are presented regarding the use of biophysical simulation for conducting similar production economic analysis; conclusions of biophysical simulation results are then given. The economic analyses performed are focused upon in the drawing of conclusions, especially regarding the economics of Blackland corn production.

Comments on the Use of Biophysical Simulation Models

With reliance on biophysical simulation models in this study to generate data and the increasing interest for this use in other applied research, a major set of comments may be developed. Recommendations involving the use of crop simulation models in general and specifically those developed by the Texas Agricultural Experiment Station at the Blackland Research Center, are presented. Experiences regarding the utilization of biophysical simulation models are discussed to provide insight to potential difficulties in their implementation. This study highlights several issues involved with the use of these models: (1) How useful were these models and were there other, better ways to obtain the same data they generated? (2) What sorts of procedures would the current research team recommend to other research teams intending to use the same or a related class of models? (3) What types of model development enhancements might model developers undertake to improve the ability of researchers to utilize these or related sets of models?

To address the usefulness of these models, a brief review of what the models were used for and what alternative sources might exist is desirable. Data on corn, grain sorghum, wheat, and cotton crop yields under various planting dates, plant populations, and maturity classes for several weather conditions were generated using the biophysical simulation models. The models were essential in generating these data because observed data (either experimental field, published, or farmer survey data) pertaining to these inputs were not available. One might be able to find a series of yield experiments pertaining to planting dates, for example, but it was not possible to find a long time series of these experiments. Nor was it possible to find data on yields under systematic variations in plant population and maturity class. In fact, the planting data available involved different locations, different maturity classes, tillage systems, and sometimes different input usages. Therefore, the models provide an important laboratory where a multitude of controlled experiments can be performed. Furthermore, where possible, validations show the models to be fairly accurate in terms of predicting changes in yields with different cultural practices or weather changes.

All things considered, these models were valuable in terms of generating essential data which otherwise would not have been available. However, a few words of caution are in order. While the crop simulation models are certainly a viable way of generating data on the effects of production management decisions for which practical data cannot be obtained, this is both an advantage and a disadvantage. It is very difficult without adequate data to validate the simulation results to determine if they are reliable. During the conduct of this study, several questions were raised as to the validity of various yield and yield variability results (e.g., were the simulated yield changes accurate as maturity classes changed). In resolving such questions, the research team sought the advice of agronomists. Usually, the simulated results were judged accurate to the best of the agronomists knowledge with the exception of conflicting opinion on maturity class results. But, again, no systematic data were available to verify the model results. This does imply that for models such as these, which are still at a relatively preliminary stage, it would be worthwhile to design field tests which develop data for calibration and validation. One still should note that such data and subsequent testing would still not fully validate the model. However, complete validation of the model in the Blackland area at Temple would not guarantee accurate results in other Blackland areas with slightly different soil types or in other areas such as in the High Plains or Coastal Bend areas of Texas.

How might other study teams go about using these types or other related models? This is addressed in two parts. Personal experiences are presented, and recommendations regarding the use and development of biophysical simulation models are then made.

It is difficult to capsulize eighteen months of experience of working with the models into a few short sentences; nevertheless, the following observations are made:

1. Initially, the models were poorly adapted to the computer system used in the study at hand. Assumptions were made within the computer programs regarding technical matters such as whether FORTRAN retained the values of variables not in common or in subroutine arguments between subroutine calls. For example, the Blackland programs assumed in cases that the variable values were retained between subroutine calls, but this was not the case for the computer system used for the study. Thus, computer specific programming presented difficulties. Therefore, the models were not readily transportable from the computers where the models were developed to the computers where they were used without considerable time and effort.
2. In generating yield results under so many different cultural conditions, it was desirable to run the models over and over, altering selected parameters (e.g., planting date, planting population, meteorological data). Almost three months of graduate student programming time was spent programming the models so that this was possible.
3. A lack of understanding on behalf of the economists of the biophysical models and their data led to

numerous model results generating inappropriate data. Many results of the cotton model were generated under California conditions because the economic researchers were not aware that internal model specifications were not for Texas Blackland conditions. Resolution of the situation required a number of meetings with model developers.

4. Even after the models were fully adapted, the cotton and wheat models consistently overestimated yield. Consequently, resultant yields were adjusted down by a multiplicative factor.

The above experiences indicate several recommendations regarding the usage of the simulation models. An important consideration that should be established as a first step is one of model selection. It is obviously vital to know whether or not the simulation model being considered has the capabilities of generating the required output data with respect to the input variables being analyzed. If one is studying yield response to nitrogen for example, the explicit inclusion of that relationship should be incorporated into the model. It is also desirable to have models which have been validated not only regarding overall output response (e.g., yield), but also with respect to changes of output response to the input factors being varied (e.g., yield response to maturity class).

At least in initial studies when researchers who are not the model developers attempt to use biophysical simulation models, it would be very worthwhile for much closer contact to be established with the model developers. The model developers should be on the research team. This will improve the quality of the analysis performed with simulation models as well as improve the simulation models themselves. It is also important for researchers using such simulation models to carefully discuss the model data with the simulation developers in order to fully understand the nature of the model parameters. This allows researchers to verify that the data are applicable to the situation they are studying. Identifying the specific parameters to be used in calibrating model results is also very useful. These latter exercises mean researchers must attempt to obtain technical documentation of the model and study it carefully. A burden is placed on model developers to make readable documentation available to potential users.

Recommendations for developers of such simulation models can also be made from this study and related research projects. Speaking generically, the simulation models had technical problems requiring reworking the FORTRAN code as discussed above. To avoid these problems, it is recommended that developers write easily understood technical documentation as well as test their models across a variety of computers and compilers. Programming in languages consistent with ANSI standards facilitates model transfer. Simulators should also be generated in modular (subroutine or procedure) form with independent modules for data input, simulation control, simulation execution, and output. As much as possible, common modules across simulators for major biophysical processes such as evapotranspiration, photosynthesis, and soil water balance would facilitate simulation comprehension, implementation, modification, and application. Further, the modules need to be tested so that repeated simulations can be done under the control of the simulation control module. Finally, while there are difficulties in incorporating more detailed simulation, the research team believes users would be very interested in the inclusion of interactions between a number of potential management variables. The research team disagrees with Musser and Tew (1984) that the results from such models cannot be interpreted and are not transferable to farm managers. During this study, the Blackland models largely only allowed changes in planting dates, planting populations, maturity classes, soil types, and weather, restricting our use of the models. Factors such as the effects of soil compaction, pests and diseases, soil nutrients, organic matter, harvesting conditions, salinity, grazing, previous crop planted, and irrigation regimes on yield should, if possible, be included. In doing this, however, developers should include recommended default settings for the parameters so that the responsibility of changing appropriate parameter values is not placed solely upon the user. Model developers could also benefit from meetings with potential users to ascertain the desirability of possible program features.

Biophysical Simulation Results

Biophysical simulation models were used to simulate the production responses to differing production management decisions. Corn, grain sorghum, wheat, and cotton models were used to simulate yields under varying weather, planting dates, plant populations, and maturity classes.

If these models are correct, then earlier planting dates always increased mean yield over the range analyzed. Furthermore, variability in yields increased with later planting dates, but weather conditions significantly affect these average results with differences arising under particular weather patterns.

For all crops, higher populations gave rise to higher mean yields. Varied results were evidenced under alternate weather conditions with the exception of wheat. High wheat populations always dominated the lower populations. The coefficient of variation associated with corn yield increased as population increased. Wheat, grain sorghum, and cotton displayed exactly the opposite trend, with their coefficient of variation being higher for low populations. Therefore, competition effects between plants for water, sunlight, and other necessities may be incompletely modeled in the four crop-growth simulation models.

Corn and grain sorghum mean yields responded differently with respect to maturity class. Corn mean yield increased as the number of days to maturity decreased, whereas short season grain sorghum varieties yielded the same as full season but relatively more than medium season varieties. Differences are evident for varied weather patterns. Both grain sorghum and corn yield coefficient of variations increased as length to maturity increased. As noted earlier, the maturity class results are suspect.

Economic Analysis

Several substantive conclusions regarding economic analysis can be made, provided the biophysical results are reliable. Corn was an important crop throughout the economic analysis. A crop mix of half corn and half cotton production is selected with wheat entering if risk aversion is present.

Wheat production replaced both corn and cotton with increasing risk aversion; therefore, increasing wheat acreage may be attractive when profit stability is required. This is expected because winter wheat is exposed to less severe moisture conditions than spring crops. Risk is also reduced by the planting of low populations of corn and of wheat but the high cotton populations remain desirable even as attention to risk continues. With increasing risk aversion, cotton acreage exceeded corn acreage planted. Increases in profit are obtained at greater and greater increases in variance.

When corn prices are varied, grain sorghum almost perfectly substitutes for corn. Low risk aversion showed greater sensitivity of expected profit, profit standard deviation, and production management strategies to changes in corn price than the higher risk aversion level. With decreases in corn price, grain sorghum production enters the solution. Corn production practices remain stable under increasing corn prices. Risk averters may also wish to begin increasing corn population under rising corn prices. Early planting dates remain advantageous.

Maximizing expected profits under corn production involves early planting, high population, and short season varieties. Of these, early planting dates are the most striking result. In the model, a substantial decrease in expected income results from later planting date, amounting roughly to 5 percent of net income per week. High and, occasionally, medium populations are selected with the later planting dates. The short season variety is planted for all planting period restrictions modeled. Altering corn population levels and maturity class cause little change in expected profit.

All in all, each of the four major crops are economically feasible at government supported prices depending on economic conditions. Cotton is very lucrative economically, with corn following closely and serving as a good crop for rotation and diversification. Wheat should be carefully considered as a means of risk reduction. Grain sorghum serves as a substitution possibility for corn or vice versa.

Limitations of the Study

An important limitation of this study is that the government support policies are not explicitly included in the economic decision model. While the economic analysis does not implicitly include detailed modeling of the farm program, three implications can be drawn regarding those operating under the farm program. First, the economic model was analyzed without specific base acreage assumptions. This was done to provide an indication of the crop mix that is desirable to move toward in adjusting base acreage. Secondly, with both corn and grain sorghum being classified as feed grains for program purposes, the interchangeability of these two production enterprises in the model indicates that corn is economically favorable to grain sorghum at current prices, if the model is correct. However, under 10 percent or lower relative corn prices, grain sorghum is more desirable. Finally, the economic analysis of the corn production decision applies to any corn grown regardless of whether it is under the farm program or not.

The results are very dependent on the biophysical simulation models used in this research. If the production data results from them are incorrect, so are the analyses conducted. Further, we could not extensively validate the set of yield responses to varying management practices because of insufficient experimental data. Finally, some missing considerations such as wheat grazing, rotational effects on crop yields (previous crop), capital requirements, and irrigation are not incorporated.

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APPENDIX 1

Experimental Design of Production Management Decisions for Biophysical Simulation Models

	CORN	GRAIN SORGHUM	WHEAT	COTTON
PLANTING DATE[1]	2/14	2/28	10/03	3/28
	2/21	3/07	10/10	4/04
	2/28	3/14	10/17	4/11
	3/07	3/21	10/24	4/18
	3/14	3/28	10/31	4/25
	3/21	4/04	11/07	5/02
	3/28	4/11	11/14	5/09
	4/04	4/18	11/21	5/16
		4/25	11/28	5/23
PLANT DENSITY[2]	15000	50000	15	20000
	19000	57500	30	42500
	26000	70000	45	80000
MATURITY CLASS[3]	Short	Short	N/A	N/A
	Medium	Medium		
	Full	Full		
ROW SPACING[4]	40	40	8	40
PLANTING DEPTH[4]	2	2	1.5	1.5

SOURCES: Coffman (1987), Jackson (1987), Metzer (1987), F. Miller (1987), T. Miller (1987), and Rosenthal (1987).

[1]Planting date is in month/day.

[2]Plant density in plants/acre for corn, grain sorghum, andcotton. Plant density for wheat is in plants/square foot.

[3]Averagedays to physiological maturity for corn are 121 days for short season, 126 days for medium season, and 129 days for full season. Average days to physiological maturity for grain sorghum are 105 days for short season, 111 days for medium season and 115 days for full season.

[4]Row spacing and planting depth are in inches.

APPENDIX 2

Tractor Time Availability

WEEK	FIELD TIME DAYS/WEEK AVERAGE	FIELD TIME DAYS/WEEK ADJUSTED[1]	TRACTOR TIME HOURS/WEEK	WEEK	FIELD TIME DAYS/WEEK AVERAGE	FIELD TIME DAYS/WEEK ADJUSTED[1]	TRACTOR TIME HOURS/WEEK
01/01-01/07	6.05	5.19	51.88	07/02-07/08	6.58	5.64	56.39
01/08-01/14	5.79	4.96	49.62	07/09-07/15	6.42	5.50	55.04
01/15-01/21	5.84	5.01	50.08	07/16-07/22	6.34	5.44	54.36
01/22-01/28	5.87	5.03	50.30	07/23-07/29	6.37	5.46	54.59
01/29-02/04	5.58	4.78	47.82	07/30-08/05	6.29	5.39	53.91
02/05-02/11	5.66	4.85	48.50	08/06-08/12	6.34	5.44	54.36
02/12-02/18	5.82	4.98	49.85	08/13-08/19	6.24	5.35	53.46
02/19-02/25	5.53	4.74	47.37	08/20-08/26	6.16	5.28	52.78
02/26-03/04	6.08	5.21	52.11	08/27-09/02	5.97	5.12	51.20
03/05-03/11	6.05	5.19	51.88	09/03-09/09	5.87	5.03	50.30
03/12-03/18	5.84	5.01	50.08	09/10-09/16	5.63	4.83	48.27
03/19-03/25	6.13	5.26	52.56	09/17-09/23	5.68	4.87	48.72
03/26-04/01	6.18	5.30	53.01	09/24-09/30	5.95	5.10	50.98
04/02-04/08	6.26	5.37	53.68	10/01-10/07	6.16	5.28	52.78
04/09-04/15	5.68	4.87	48.72	10/08-10/14	5.87	5.03	50.30
04/16-04/22	5.26	4.51	45.11	10/15-10/21	5.95	5.10	50.98
04/23-04/29	5.42	4.65	46.47	10/22-10/28	5.87	5.03	50.30
04/30-05/06	5.42	4.65	46.47	10/29-11/04	5.47	4.69	46.92
05/07-05/13	5.24	4.49	44.89	11/05-11/11	5.89	5.05	50.53
05/14-05/20	5.68	4.87	48.72	11/12-11/18	6.03	5.17	51.65
05/21-05/27	5.66	4.85	48.50	11/19-11/25	5.58	4.78	47.82
05/28-06/03	5.84	5.01	50.08	11/26-12/02	5.74	4.92	49.17
06/04-06/10	5.79	4.96	49.62	12/03-12/09	6.18	5.30	53.01
06/11-06/17	6.05	5.19	51.88	12/10-12/16	5.66	4.85	48.50
06/18-06/24	5.84	5.01	50.08	12/17-12/23	6.03	5.17	51.65
06/25-07/01	6.11	5.23	52.33	12/24-12/31	6.08	5.21	52.11

[1]Adjusted refers to multiplying by 6/7 under the assumption that only 6 days per week are worked.

APPENDIX 3

Table 1. Corn Machinery Operations Sequencing Diagram.

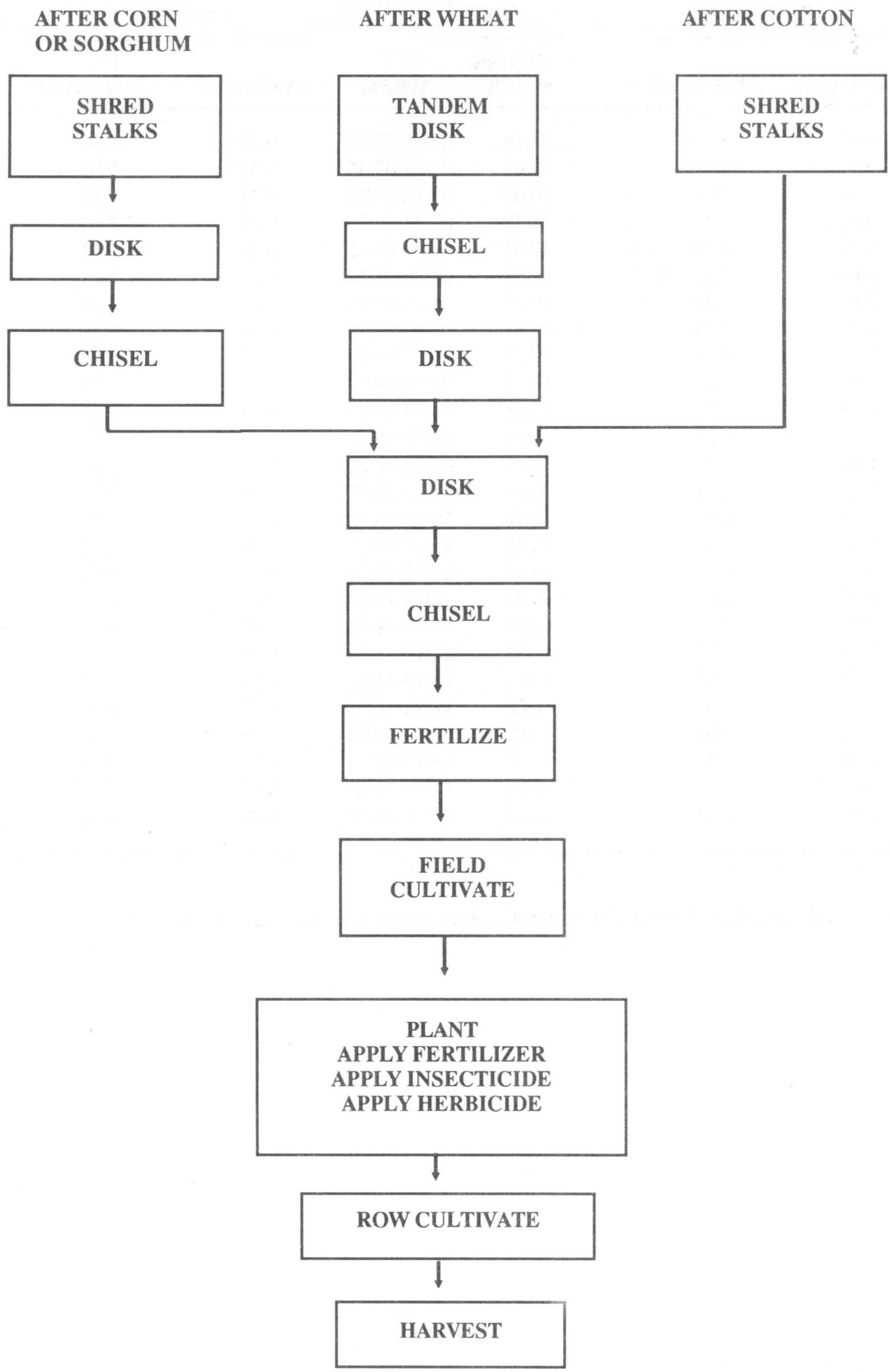

Table 2. Corn—Operation Timetable.

CLASS	OPERATION	FEASIBLE WEEK OF PERFORMANCE[1]
AFTER CORN OR GRAIN SORGHUM	SHRED STALKS	7/16-7/22 or 7/23-7/29
	DISK	7/23-7/29 or 7/30-8/05
	CHISEL	8/06-8/12 or 8/13-8/19
AFTER WHEAT	TANDEM DISK	5/28-6/03 or 6/04-6/10
	CHISEL	5/28-6/03 or 6/04-6/10
	DISK	7/23-7/29 or 7/30-8/05
AFTER COTTON	SHRED STALKS	7/30-8/05 or 8/06-8/12
AFTER REMOVAL OF PRIOR CROP RESIDUE	DISK	8/20-8/26 or 8/27-9/02
	CHISEL	9/17-9/23 or 9/24-9/30
	FERTILIZE	1/08-1/14 or 1/15-1/21
	FIELD CULTIVATE – ONE	1/15-1/21 or 1/22-1/28
	PLANT[1]	2/12-2/18
	ROW CULTIVATE – SHORT SEASON MATURITY CLASS (3.5 FEET CULTIVATOR)	3/05-3/11 or 3/12-3/18
	ROW CULTIVATE – MEDIUM SEASON MATURITY CLASS (3.5 FEET CULTIVATOR)	3/12-3/18 or 3/19-3/25
	ROW CULTIVATE – FULL SEASON MATURITY CLASS (3.5 FEET CULTIVATOR)	3/19-3/25 or 3/26-4/01
	HARVEST – SHORT SEASON MATURITY CLASS	7/02-7/08 or 7/09-7/15
	HARVEST – MEDIUM SEASON MATURITY CLASS	7/09-7/15 or 7/16-7/22
	HARVEST – FULL SEASON MATURITY CLASS	7/16-7/22 or 7/23-7/29

[1]These feasible time periods are for the first planting time period modeled (week 2/12-2/18). For later planting dates (weeks 2/19-2/25 through 4/2-4/8), add one week for each week removed from week 2/12- 2/18. For example, shredding stalks after corn or grain sorghum is done in week 7/23-7/29 or 7/30-8/5 for planting week 2/19-2/25, week 7/30-8/5 or 8/6-8/12 for planting week 2/26-3/4, etc.

Table 3. Grain Sorghum Machinery Operations Sequencing Diagram.

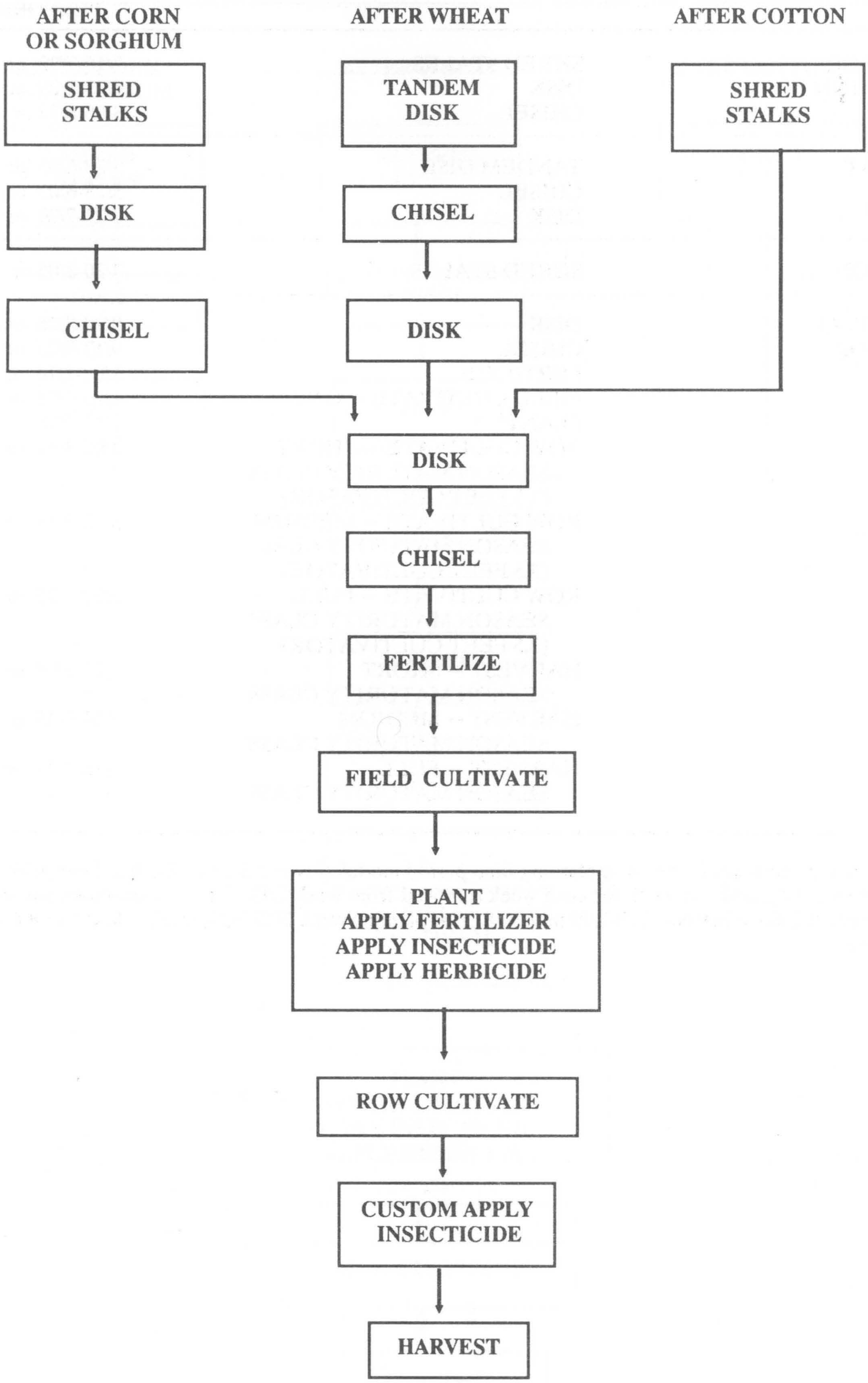

Table 4. **Grain Sorghum – Operation Timetable.**

CLASS	OPERATION	FEASIBLE WEEK OF PERFORMANCE[1]
AFTER CORN OR GRAIN SORGHUM	SHRED STALKS	7/16-7/22 or 7/23-7/29
	DISK	7/16-7/22 or 7/23-7/29
	CHISEL	7/30-8/05 or 8/06-8/12
AFTER WHEAT	TANDEM DISK	5/21-5/27 or 5/28-6/03
	CHISEL	5/21-5/27 or 5/28-6/03
	DISK	7/16-7/22 or 7/23-7/29
AFTER COTTON	SHRED STALKS	7/30-8/05 or 8/06-8/12
AFTER REMOVAL OF PRIOR CROP RESIDUE	DISK	8/20-8/26 or 8/27-9/02
	CHISEL	9/17-9/23 or 9/24-9/30
	FERTILIZE	1/08-1/14 or 1/15-1/21
	FIELD CULTIVATE – TWO	2/05-2/11 or 2/12-2/18
	PLANT[1]	2/26-3/04
	ROW CULTIVATE – SHORT SEASON MATURITY CLASS (3.5 FEET CULTIVATOR)	3/19-3/25 or 3/26-4/01
	ROW CULTIVATE – MEDIUM SEASON MATURITY CLASS (3.5 FEET CULTIVATOR)	3/26-4/01 or 4/02-4/08
	ROW CULTIVATE – FULL SEASON MATURITY CLASS (3.5 FEET CULTIVATOR)	4/02-4/08 or 4/09-4/15
	ROW CULTIVATE – SHORT SEASON MATURITY CLASS (5.0 FEET CULTIVATOR)	4/16-4/22 or 4/23-4/29
	ROW CULTIVATE – MEDIUM SEASON MATURITY CLASS (5.0 FEET CULTIVATOR)	4/23-4/29 or 4/30-5/06
	ROW CULTIVATE – FULL SEASON MATURITY CLASS (5.0 FEET CULTIVATOR)	4/30-5/06 or 5/07-5/13
	HARVEST – SHORT SEASON MATURITY CLASS	6/25-7/01 or 7/02-7/08
	HARVEST – MEDIUM SEASON MATURITY CLASS	7/02-7/08 or 7/09-7/15
	HARVEST – FULL SEASON MATURITY CLASS	7/09-7/15 or 7/16-7/22

[1]These feasible time periods are for the first planting time period modeled (week 2/26-3/4). For later planting dates (weeks 3/5-3/11 through 4/23-4/29), add one week for each week removed from 2/26-3/4. For example, shredding stalks after corn or grain sorghum is done in week 7/23-7/29 or 7/30-8/5 for planting week 3/5-3/11, week 7/30-8/5 or 8/6- 8/12 for planting week 3/12-3/18, etc.

Table 5. Wheat Machinery Operations Sequencing Diagram.

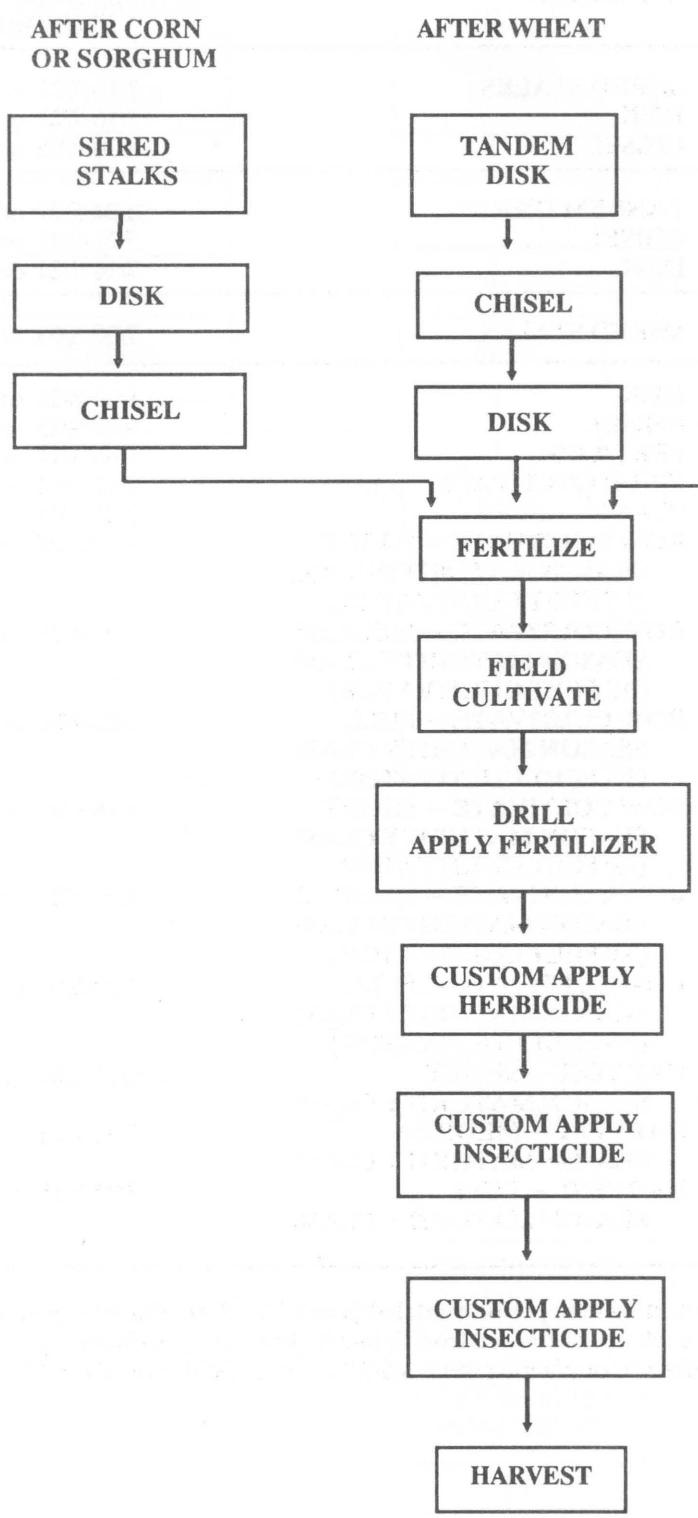

Table 6. Wheat – Operation Timetable.

CLASS	OPERATION	FEASIBLE WEEK OF PERFORMANCE[1]
AFTER CORN OR OR GRAIN SORGHUM	SHRED STALKS	7/09-7/15 or 7/16-7/22
	DISK	7/09-7/15 or 7/16-7/22
	CHISEL	7/23-7/29 or 7/30-8/05
AFTER WHEAT	TANDEM DISK	5/07-5/13 or 5/14-5/20
	CHISEL	5/14-5/20 or 5/21-5/27
	DISK	7/09-7/15 or 7/16-7/22
AFTER COTTON	SHRED STALKS	7/09-7/15 or 7/16-7/22
	CHISEL	8/06-8/12 or 8/13-8/19
AFTER REMOVAL OF PRIOR CROP RESIDUE	FIELD CULTIVATE - ONE	9/03-9/09 or 9/10-9/16
	FERTILIZE	8/20-8/26 or 8/27-9/02
	DRILL[1]	10/01-10/07
	HARVEST	4/30-5/05 or 5/07-5/13

[1]These feasible time periods are for the first planting time period modeled (week 10/1-10/7). For later planting dates (weeks 10/8-10/14 through 11/26-12/2), add one week for each week removed from week 10/1-10/7. For example, shredding stalks after corn or grain sorghum is done in week 7/16-7/22 or 7/23-7/29 for planting week 10/8-10/14, week 7/23-7/29 or 7/30-8/5 for planting week 10/15-10/21, etc.

Table 7. Cotton Machinery Operations Sequencing Diagram.

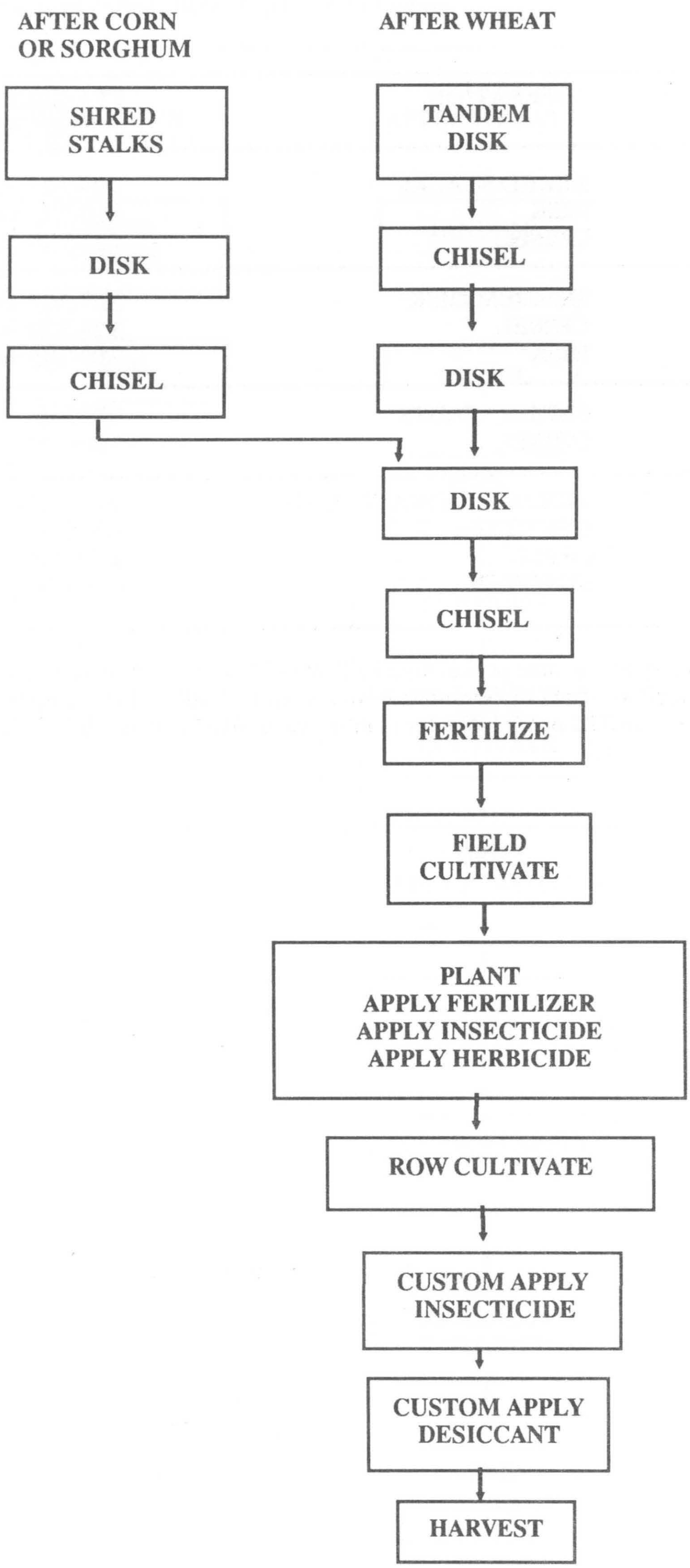

Table 8. Cotton — Operation Timetable.

CLASS	OPERATION	FEASIBLE WEEK OF PERFORMANCE[1]
AFTER CORN OR GRAIN SORGHUM	SHRED STALKS	7/09-7/15 or 7/16-7/22
	DISK	7/09-7/15 or 7/16-7/22
	CHISEL	7/23-7/29 or 7/30-8/05
AFTER WHEAT	TANDEM DISK	5/14-5/20 or 5/21-5/27
	CHISEL	5/14-5/20 or 5/21-5/27
	DISK	7/09-7/15 or 7/16-7/22
AFTER REMOVAL OF PRIOR CROP RESIDUE	DISK	8/13-8/19 or 8/20-8/26
	CHISEL	9/10-9/16 or 9/17-9/23
	FERTILIZE	1/22-1/28 or 1/29-2/04
	FIELD CULTIVATE - ONE	3/05-3/11 or 3/12-3/18
	PLANT[1]	3/26-4/01
	ROW CULTIVATE (5.0 FEET CULTIVATOR)	4/16-4/22 or 4/23-4/29
	ROW CULTIVATE (3.5 FEET CULTIVATOR)	5/21-5/27 or 5/28-6/03
	HARVEST	7/30-8/05 or 8/06-8/12

[1]These feasible time periods are for the first planting time period modeled for each week removed from week 3/26-4/1. For example, shredding stalks after corn or grain sorghum is done in week 7/16-7/22 or 7/23-7/29 for planting week 4/2-4/8, week 7/23-7/29 or 7/30-8/5 for planting week 4/9-4/15, etc.

APPENDIX 4

Table 1. Corn – Production Input Requirements per Acre.

Section I. Tractor and Implement Related Inputs

OPERATION	FUEL (GALLONS)	LUBE (DOLLARS)	REPAIRS AND MAINTENANCE (DOLLARS)	LABOR (HOURS)	TRACTOR (LARGE OR SMALL)
SHRED STALKS	0.5069	0.0466	0.1760	0.1134	SMALL
TANDEM DISK	0.8794	0.0809	0.3350	0.1311	LARGE
DISK	0.8794	0.0809	0.3350	0.1311	LARGE
CHISEL	0.9227	0.0848	0.2332	0.1361	LARGE
FERTILIZE	0.6000	0.0552	0.2067	0.0972	LARGE
FIELD CULTIVATE – ONE	0.5000	0.0460	0.1530	0.0810	LARGE
PLANT	0.2432	0.0223	0.7660	0.2016	SMALL
ROW CULTIVATE (3.5 FEET CULTIVATOR)	0.4235	0.0389	0.2707	0.1944	SMALL

Section II. Other Production Inputs

OPERATION	FERTILIZER 10-34-0 (POUNDS)	NITROGEN NH_3 (POUNDS)	GENERAL HERBICIDE (POUNDS)	CORN HERBICIDE (POUNDS)	GENERAL INSECTICIDE (GALLONS)	SEED (POUNDS)
FERTILIZE	50.00	165.00				
PLANT	100.00		0.7500	1.00	0.1875	
15000/Acre						13.20
19000/Acre						16.72
26000/Acre						22.88

Section III. Operating Capital

	OPERATING CAPITAL (DOLLARS)
AFTER CORN OR GRAIN SORGHUM	52.19
AFTER WHEAT	53.79
AFTER COTTON	46.57

Table 2. Grain Sorghum – Production Input Requirements per Acre.

Section I. Tractor and Implement Related Inputs

OPERATION	FUEL (GALLONS)	LUBE (DOLLARS)	REPAIRS AND MAINTENANCE (DOLLARS)	LABOR (HOURS)	TRACTOR (LARGE OR SMALL)
SHRED STALKS	0.5069	0.0466	0.1760	0.1134	SMALL
TANDEM DISK	0.8794	0.0809	0.3350	0.1311	LARGE
DISK	0.8794	0.0809	0.3350	0.1311	LARGE
CHISEL	0.9227	0.0848	0.2332	0.1361	LARGE
FERTILIZE	0.6000	0.0552	0.2067	0.0972	LARGE
FIELD CULTIVATE - TWO	0.4376	0.0402	0.1391	0.0708	LARGE
PLANT	0.2432	0.0223	0.7660	0.2016	SMALL
ROW CULTIVATE (3.5 FEET CULTIVATOR)	0.4235	0.0389	0.2707	0.1944	SMALL
ROW CULTIVATE (5.0 FEET CULTIVATOR)	0.2964	0.0272	0.1894	0.1361	SMALL

Section II. Other Production Inputs

OPERATION	FERTILIZER 10-34-0 (POUNDS)	NITROGEN NH_3 (POUNDS)	GENERAL HERBICIDE (POUNDS)	GRAIN SORGHUM HERBICIDE (GALLONS)	GENERAL INSECTICIDE (GALLONS)	SEED (POUNDS)
FERTILIZE	50.00	134.00				
PLANT	100.00		0.7500	0.1875	0.1875	
50000/Acre						4.1667
57500/Acre						4.7917
70000/Acre						5.8333

Continued on next page.

Table 2. Continued.

Section III. Custom Operations

CUSTOM OPERATION	NUMBER OF APPLICATIONS (GALLONS)	CUSTOM INSECTICIDE
CUSTOM INSECTICIDE APPLICATION	1.00	0.0310

Section IV. Operating Capital

	OPERATING CAPITAL (DOLLARS)
AFTER CORN OR GRAIN SORGHUM	41.90
AFTER WHEAT	45.54
AFTER COTTON	36.36

Table 3. Wheat – Production Input Requirements per Acre.

Section I. Tractor and Implement Related Inputs

OPERATION	FUEL (GALLONS)	LUBE (DOLLARS)	REPAIRS AND MAINTENANCE (DOLLARS)	LABOR (HOURS)	TRACTOR (LARGE OR SMALL)
SHRED STALKS	0.5069	0.0466	0.1760	0.1134	SMALL
TANDEM DISK	0.8794	0.0809	0.3350	0.1311	LARGE
DISK	0.8794	0.0809	0.3350	0.1311	LARGE
CHISEL	0.9227	0.0848	0.2332	0.1361	LARGE
FERTILIZE	0.6000	0.0552	0.2067	0.0972	LARGE
FIELD CULTIVATE – ONE	0.5000	0.0460	0.1530	0.0810	LARGE
DRILL	0.1824	0.0167	0.3672	0.1512	SMALL

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Table 3. Continued.

Section II. Other Production Inputs

OPERATION	FERTILIZER 10-34-0 (POUNDS)	NITROGEN NH_3 (POUNDS)	SEED (POUNDS)
FERTILIZE	50.00	61.00	
DRILL	50.00		
- 15 PLANTS/SQ. FT.			52.5054
- 30 PLANTS/SQ. FT.			105.0107
- 45 PLANTS/SQ. FT.			157.5161

Section III. Custom Operations

CUSTOM OPERATION	NUMBER OF APPLICATIONS	CUSTOM INSECTICIDE (GALLONS)	WHEAT HERBICIDE(1) (POUNDS)	WHEAT HERBICIDE(2) (GALLONS)
CUSTOM INSECTICIDE APPLICATION	2.00	0.0310 PER APPLICATION		
CUSTOM HERBICIDE APPLICATION	1.00		0.1250	0.3300

Section IV. Operating Capital

	OPERATING CAPITAL (DOLLARS)
AFTER CORN OR GRAIN SORGHUM	43.90
AFTER WHEAT	45.59
AFTER COTTON	41.46

Table 4. Cotton – Production Input Requirements per Acre.

Section I. Tractor and Implement Related Inputs

OPERATION	FUEL (GALLONS)	LUBE (DOLLARS)	REPAIRS AND MAINTENANCE (DOLLARS)	LABOR (HOURS)	TRACTOR (LARGE OR SMALL)
SHRED STALKS	0.5069	0.0466	0.1760	0.1134	SMALL
TANDEM DISK	0.8794	0.0809	0.3350	0.1311	LARGE
DISK	0.8794	0.0809	0.3350	0.1311	LARGE
CHISEL	0.9227	0.0848	0.2332	0.1361	LARGE
FERTILIZE	0.6000	0.0552	0.2067	0.0972	LARGE
FIELD CULTIVATE – ONE	0.5000	0.0460	0.1530	0.0810	LARGE
PLANT	0.2432	0.0223	0.7660	0.2016	SMALL
ROW CULTIVATE (5.0 FEET CULTIVATOR)	0.2964	0.0272	0.1894	0.1361	SMALL
ROW CULTIVATE (3.5 FEET CULTIVATOR)	0.4235	0.0389	0.2707	0.1944	SMALL

Section II. Other Production Inputs

OPERATION	FERTILIZER 10-34-0 (POUNDS)	NITROGEN NH_3 (POUNDS)	GENERAL HERBICIDE (POUNDS)	COTTON HERBICIDE (POUNDS)	SEED (POUNDS)
FERTILIZE	50.00	49.00			
PLANT	50.00		0.7500	0.7500	
20000/Acre					5.8824
42500/Acre					12.5000
80000/Acre					23.5294

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Table 4. Continued.

Section III. Custom Operations

CUSTOM OPERATION	NUMBER OF APPLICATIONS	GENERAL INSECTICIDE (GALLONS)	DESICCANT ACID (GALLONS)
CUSTOM INSECTICIDE APPLICATION	2.00	0.1880 PER APPLICATION	
CUSTOM DESICCANT ACID APPLICATION	1.00		0.5000

Section IV. Operating Capital

	OPERATING CAPITAL (DOLLARS)
AFTER CORN OR GRAIN SORGHUM	50.15
AFTER WHEAT	51.88

APPENDIX 5

Section I. Input Prices

INPUT	INPUT PRICE PER UNIT	UNITS
FUEL	0.92	GALLONS
LUBE	1.00	DOLLARS
LABOR	5.00	HOURS
OPERATING CAPITAL	0.13	DOLLARS
FERTILIZER (10-34-0)	0.107	POUNDS
NITROGEN (NH_3)	0.095	POUNDS
GENERAL INSECTICIDE	50.10	GALLONS
CUSTOM INSECTICIDE	248.40	GALLONS
GENERAL HERBICIDE	5.937	POUNDS
CORN HERBICIDE	4.50	POUNDS
GRAIN SORGHUM HERBICIDE	13.00	GALLONS
WHEAT HERBICIDE(1)	12.50	POUNDS
WHEAT HERBICIDE(2)	15.22	GALLONS
COTTON HERBICIDE	6.35	POUNDS
DESICCANT ACID	9.75	GALLONS
CUSTOM APPLICATION COST (HERBICIDE, INSECTICIDE, OR DESICCANT ACID)	2.75	APPLICATION

Section II. Seed Prices and Harvest Hauling Costs

CROP	SEED PRICE PER POUND	HARVEST AND HAULING COSTS
CORN	0.9697	0.14 / BU + 15.00 / ACRE
GRAIN SORGHUM	0.8350	0.65 / CWT
WHEAT	0.1920	0.12 / BU + 12.00 / ACRE
COTTON	0.4000	0.1649 / LB (COTTON LINT)

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