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SIMULATION ANALYSIS USING PHYSIOLOGICAL CROP-RESPONSE MODELS

ALTERNATIVE CROPPING STRATEGIES FOR SOUTHWEST KANSAS

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SIMULATION ANALYSIS USING PHYSIOLOGICAL CROP-RESPONSE MODELS: ALTERNATIVE CROPPING STRATEGIES FOR SOUTHWEST KANSAS[1]

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ABSTRACT

Physiological crop-response models, which take into account the dynamics of plant responses to soil moisture, were used for the first time to evaluate alternative cropping strategies involving three different crops. Dryland and fallow cropping and various levels of irrigation in Southwest Kansas were considered for each of three crops (corn, grain sorghum, and wheat) with the models CERES, SORGF, and PHOTO, respectively. The models were validated by simulating yields for field experiments done at the Southwest Kansas Branch Station over an 8-year period. Simulated yields for corn were quite close to actual yields; those for grain sorghum tended more to exceed actual yields; and those for wheat tended to be slightly below actual yields. Next, the models were used with 28 years of meteorological data to simulate for each growing season the yields and returns for each cropping strategy. Then, each strategy was evaluated, based on its distribution of yields and returns. Depending on grain prices, the most profitable strategies would be corn irrigated with 16 inches of water; sorghum-fallow and sorghum irrigated with 12 inches of water; and wheat-fallow and wheat irrigated with 8 to 12 inches of water. Choice of strategy is also affected by irrigation cost and limited water supplies. The usefulness of physiological crop-response models for evaluating cropping strategies will increase as improvements are added to better predict yields.

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INTRODUCTION

The Models

Most of the present economic analysis of crops is based on average yields, sometimes estimated by production function analysis. Such analysis has limitations for dealing with the dynamics of soil moisture utilization in crop production. Mathematical models based on the physical and biological processes involved in the daily growth and development of the plant offer a means to study the dynamics of plant response to soil moisture, an aspect critical to the understanding of water use in crop production in semi-arid areas. Such a model shall be referred to here as a physiological crop-response model.

A model consists of a set of mathematical relations, each of which describes the relationship that the value of one variable has with the values of other variables. In a physiological crop-response model, each mathematical relation describes some physiological process associated with the plant's growth and development or some physical process associated with the plant's microenvironment. For example, one relationship could describe how the available soil moisture changes from one day to the next, given the factors affecting soil moisture, e.g., the meteorological conditions, the condition of the crop, and the amount of irrigation water applied during that interval.

The complete set of mathematical relations, i.e., the model, together with the values of those variables required as inputs to the model, define a solution. Such a solution is called a simulation because the solution is an attempt to simulate or replicate mathematically actual crop growth and development. A key output of the simulation is the simulated yield, which is a prediction or estimation of the yield that would occur under the given conditions. When the model is translated to computer code, a computer can be used to make the calculations for the simulation.

Such physiological crop-response models have been used by agronomists and agricultural engineers to study technical aspects of crop production that cannot be studied readily with controlled experiments. They have been used also by agricultural economists to study the economics of irrigation scheduling (Harris et al., 1983 and Zavaleta et al., 1980). So far, they have not been used to select from among alternative crops and cropping strategies.

In economic analysis, those models are most valuable when one or more yield-determining factors under study are (1) uncontrollable, (2) highly variable throughout the growing season, and (3) usually yield limiting. Natural precipitation, particularly as it occurs on the High Plains, is a good example of such a factor in dryland and limited irrigation production. Physiological crop-response models that incorporate plant-water relationships offer the potential for estimating yield distributions for each of many possible cropping strategies.

The Location

On the High Plains of Kansas, irrigation increased dramatically after World War II, and by 1985 nearly 2 million acres were devoted to the irrigated production of wheat, corn, grain sorghum, and soybeans. However, declining groundwater supplies and, more recently, lower grain prices have reduced the economic returns to irrigation and have stimulated interest in the economic viability of alternative cropping strategies.

In a 1982 study done for the High Plains Study Council, Orlan Buller projected the changes in irrigated crop acres for 32 western Kansas counties. Those projections were based on the solution of a linear programming model to select the most profitable enterprise combination consistent with the resource and production constraints. With the assumptions of constant real grain prices (adjusted for inflation) and declining groundwater availability, he projected changes in irrigated acres between 1977 and 1985 as follows: corn down 42 percent, grain sorghum down 34 percent, wheat down 15 percent, and soybeans down to near zero acreage. Changing the assumptions to rising real grain prices and improving irrigation efficiency produced smaller projected declines in irrigated acreage for 1985, particularly for corn, and actually an increase in soybean acreage. Depending on the assumptions made, the combined irrigated acres of the four crops were projected to fall from 10 to 40 percent during the 8-year period.

The transition is not occurring as projected. The actual changes in irrigated acreage between 1977 and 1985 were as follows: corn down 53 percent, grain sorghum up 24 percent, wheat up 68 percent, and soybeans up fivefold. The combined irrigated acreage of those crops in 1985 was virtually the same as it was in 1977. Acreage in irrigated grain sorghum, wheat, and soybeans was higher in 1985, even though real grain prices were lower than in 1977. The acreage in dryland grain sorghum production was up 140 percent, whereas the acreage in dryland wheat production was down 10 percent. The bulk of the adjustments consisted of switching from irrigated corn production and dryland wheat production to irrigated wheat production and to dryland and irrigated grain sorghum production.

The discrepancy between the transition taking place and the projected transition indicates that factors not considered in the projection analysis have been operative. For example, the discovery that the new semidwarf wheat variety, Newton, is more responsive to irrigation improved the comparative advantage of irrigated wheat production in Kansas.

An aspect that merits analysis is the potential for reducing the use of irrigation water and for adopting improved dryland methods. As one goes from full irrigation to limited irrigation and then to dryland cropping, soil moisture (and, hence, yield) becomes more and more dependent on the weather conditions encountered during the growing season. That is particularly true when the crop grown has a seasonal consumptive demand that exceeds the average annual rainfall, e.g., grain production on the High Plains of Kansas. Under those conditions, differences in weather alone can produce considerable differences in yield, so knowledge of the average yield for a cropping strategy may not be sufficient for choosing among strategies. The distribution of yields associated with the distribution of weather conditions is needed for each potential cropping strategy.

Here we report the results of using physiological crop-response models for the first time to study cropping strategies for three crops at a particular location on the High Plains of Kansas. The three crops considered were corn, grain sorghum, and wheat. The cropping strategies studied for each crop were continuous dryland cropping, fallow cropping, and eight different irrigation regimes. The objective was to determine for each cropping strategy the distribution of yields and returns associated with the climatic conditions at the location.

The Garden City, Kansas, area was chosen as the study site for three reasons. First, it is near the center of the High Plains of Kansas, in the area where irrigation is most extensive and where transitions in cropping systems are occurring. Second, the Southwest Kansas Branch Experiment Station[3] provided a wealth of test-plot data with which to test the predictive accuracy of the models. Third, except for solar radiation, the required meteorological data have been recorded at Garden City. The solar radiation has been recorded at Dodge City, which is only 50 miles away.

PROCEDURES

Models

The physiological crop-response models selected were the CERES corn growth model developed in Texas (Jones et al., 1985), the SORGF grain sorghum model developed in Texas (Arkin et al., 1976) and modified for Kansas conditions by Vanderlip, and the PHOTO wheat growth model developed at Kansas State University (Brakke and Kanemasu, 1979).

The models are similar. Differences among the models can be attributed mostly to physiological differences in the crops being simulated. The major components of each model are (1) daily soil moisture determination, (2) daily leaf area development, and (3) daily dry matter accumulation and the allocation of that dry matter among the parts of the plant. The dry matter allocated to the grain parts of the plant determines the harvestable yield at maturity.

These models concentrate on the relationship between soil moisture and plant growth, while other production factors such as tillage practices and soil fertility are held fixed. The models assume that pests and short-duration, intense climatic conditions, such as hail, wind storms, and extreme levels of evaporative demand in the atmosphere, do not occur to reduce yield. With each model and for a given soil, differences in simulated yields result from differences in weather conditions and water applications during the growing season and from differences in available soil moisture at planting. The CERES model also accounts for differences in genotype.

The inputs required by each model to simulate a crop yield are of three types: specific to the crop, specific to the soil, and daily meteorological and water application observations. The crop-related inputs are plant spacing and population, seeding depth, and coefficients for the genotype of the plant. The soil-related inputs are the moisture holding capacity, the permanent wilting point, the initial soil moisture content, coefficients for drainage through the soil profile, a surface runoff coefficient, and stage 1 and stage 2 surface evaporation coefficients. Because the corn and the wheat models divide the root zone into layers, they require the specification of the soil coefficients for each layer. (See Appendix, Table 1 for a complete listing of inputs.)

Validation Tests

Results of field trials run at the Southwest Kansas Branch Experiment Station were used to validate (i.e., check the predictive accuracy of) each of the three crop growth models. The appropriate crop growth model was used to simulate the yield for each experimental trial. We compared average, maximum, and minimum yields and regressed actual yields against simulated yields.

For each of the three crops, field trials were identified for which the data required to simulate the trials had been recorded. Those trials had been run during some growing season between 1975 and 1983. From the record of each trial, we obtained the data on soil parameters, initial soil moisture conditions, crop variety, planting date, plant population, date of each irrigation and the amount applied, and the harvested yield.

The corn experiments were run on Richfield loam soils; the wheat and grain sorghum experiments prior to 1977 were run on Ulysses loam soils and since then on Satanta loam soils. The total water in a 5-foot root zone at permanent wilting point is 9.8 inches for the Richfield loam soil and 7.01 inches for the Ulysses loam and the Satanta loam soils. The maximum water available to the plant that these soils can hold in a 5-foot depth is 10.2 inches.

All test plots that received a preplant irrigation were assumed to be at field capacity at planting. For the mid-July irrigation treatments, an initial value of 50 percent available soil moisture was assumed.

Genotypical coefficients for the corn varieties were obtained by personal correspondence with J. R. Kiniry at the Grassland Soils and Water Research Laboratory. The maximum leaf area values for grain sorghum were obtained from Baker's thesis (1982).

The daily meteorological readings were obtained from the National Climatic Data Center records collected at Garden City and Dodge City. Daily minimum and maximum temperatures and precipitation as collected at the Garden City reporting station were used. Because solar radiation measurements were not recorded at Garden City before

[3]Formerly known as the Garden City Branch Experiment Station.

1980, we used solar radiation data collected through 1980 at the closest station, Dodge City. For the period after 1980, we used actual readings made at Garden City. However, some of those readings were missing. When single day readings were missing, we used an average of the readings the day before and the day after the missing readings. Twice, readings were missing for periods of 2 weeks. Readings from the corresponding time period for another year drawn at random were used for those.

Simulations

In this phase of the work, we used the crop growth models to simulate yields for the cropping strategies shown in Table 1. The cropping strategies considered for each crop were continuous dryland cropping, fallow, and various levels of irrigation, ranging from 4 to 16 inches of water applied.

For each crop, a particular soil and genotype were used throughout the simulations. We used the same meteorological data for the simulations and for the validations, except that the data for the simulations extended over a longer time period–1955 through 1983. We consider 29 years of weather data to be a representative sample of the possible weather conditions, so that the set of yields simulated for a strategy should be a good representation of the distribution of possible yields for that strategy.

Critical to the yield of any crop is the amount of precipitation that falls during the growing season. Table 2 shows the precipitation that fell during each growing season from 1955 through 1983. The precipitation is shown for two different periods. One period, extending from April 1 to September 1, roughly coincides with the growing season for corn and grain sorghum. The other, extending from September 1 to July 1 of the next year, roughly coincides with the growing season for winter wheat. Also shown are the summary statistics on the precipitation that fell during those two periods. Note the high year-to-year variability in the precipitation amounts.

The four different initial-soil-moisture series used in the simulations are shown in Table 2. For each crop, the same series was used for continuous irrigation as for continuous dryland. In doing that, we have assumed that the level of soil moisture depletion at harvest is the same in both cases. An argument could be made that depletion should be less under irrigation. The counter argument is that an efficient irriga-

Table 1. List of cropping strategies used in simulations

Code	Description
	Corn Cropping Strategies
CC	Dryland production
CF	Corn fallow rotation
PP-4	4″ irrigation before planting
PP-8	8″ irrigation before planting
Mid-July	4″ irrigation in mid-July
PP-4+TAS	4″ irrigation before planting and 4″ irrigation just before tasseling
PP-8+TAS	8″ irrigation before planting and 4″ irrigation just before tasseling
PP-4+TAS+BEG	4″ irrigation before planting, 4″ irrigation before tasseling and 4″ irrigation at beginning of ear growth
PP-8+TAS+BEG	8″ irrigation before planting, 4″ irrigation before tasseling and 4″ irrigation at beginning of ear growth
PP-4+TAS+T-B+BEG	4″ irrigation before planting, 4″ irrigation before tasseling, 4″ irrigation between tasseling and beginning of ear growth, and 4″ irrigation at beginning of ear growth
	Grain Sorghum Cropping Strategies
SS	Dryland production
SF	Sorghum fallow rotation
PP-4	4″ irrigation before planting
PP-8	8″ irrigation before planting
Mid-July	4″ irrigation in mid-July
PP-4+9LF	4″ irrigation before planting and 4″ irrigation at 9 leaf stage
PP-8+9LF	8″ irrigation before planting and 4″ irrigation at 9 leaf stage
PP-4+9LF+BT	4″ irrigation before planting, 4″ irrigation at 9 leaf stage and 4″ irrigation at boot stage
PP-8+9LF+BT	8″ irrigation before planting, 4″ irrigation at 9 leaf stage and 4″ irrigation at boot stage
PP-4+9LF+BT+FL	4″ irrigation before planting, 4″ irrigation at 9 leaf stage, 4″ irrigation at boot stage, and 4″ irrigation at flowering
	Wheat Cropping Strategies
WW	Dryland Production
WF	Wheat fallow rotation
PP-4	4″ irrigation before planting
PP-8	8″ irrigation before planting
PP-4+BT	4″ irrigation before planting and 4″ irrigation at boot stage
PP-8+BT	8″ irrigation before planting, and 4″ irrigation at boot stage
PP-4+BT+SD	4″ irrigation before planting, 4″ irrigation at boot stage, and 4″ irrigation at soft dough stage
PP-8+BT+SD	8″ irrigation before planting, 4″ irrigation at boot stage, and 4″ irrigation at soft dough stage
PP-4JT+BT+SD	4″ irrigation before planting, 4″ irrigation at jointing, 4″ irrigation at boot stage, and 4″ irrigation at soft dough stage
	Mixed Crop Strategy
WSF	Wheat first year, sorghum second year, and fallow the third year

tion schedule would still allow the crop to deplete much of the available soil moisture by harvest.

Two data sets were used to develop the soil moisture series shown in Table 2. The estimates for 1955-1974 were developed from soil moisture estimates made by Bark et al. (1977). He estimated soil moisture at April 15 and October 15 for continuous wheat and for wheat fallow. For initial soil moisture, we used the October 15 estimates for wheat and the April 15 estimates for corn and sorghum. The estimates for 1975-1983 were developed from soil moisture measurements made by Norwood (1984) at the Southwest Branch Experiment Station. He measured initial soil moisture for wheat-fallow and for sorghum-fallow. Estimates for continuous dryland and irrigated production were obtained by subtracting a fixed amount from each year's fallow measure so that the series for corn and sorghum (continuous dryland and irrigated) for those years averaged 4.25 inches. Continuous dryland and irrigated wheat estimates were made similarly, except that the average was set at 4 inches.

Using the input data developed, we estimated for each year the yield for each cropping strategy. That produced 29 simulated yields for each corn or grain sorghum cropping strategy and 28 simulated yields for each wheat cropping strategy. One fewer yield simulation was obtained for wheat because, in Kansas, the growing season for winter wheat starts in one calendar year and ends in the next. The set of yields for each cropping strategy provides an estimate of the yield distribution for that strategy.

Table 2. Initial soil moisture for each simulation and seasonal precipitation

	Initial Soil Moisture (inches available)				Precipitation (inches of water)	
Year	Sor & Corn Fallow	Sor & Corn Irr & Cont	Wheat Fallow	Wheat Irr & Cont	April 1 to Sept 1	Sept 1 to July 1
1983	7.29	3.05	7.29	3.27	11.19	—
1982	7.28	3.04	8.35	4.33	14.93	15.87
1981	7.63	3.39	7.49	3.47	11.49	15.32
1980	8.24	4.00	7.75	3.73	12.44	7.23
1979	7.34	3.10	8.05	4.03	14.71	15.27
1978	9.74	5.50	7.54	3.52	9.63	10.23
1977	8.79	4.55	9.69	5.67	18.19	14.90
1976	8.39	4.15	8.09	4.07	7.29	15.61
1975	9.49	5.25	7.89	3.87	11.15	9.31
1974	10.51	6.86	9.56	6.50	7.46	11.58
1973	8.95	5.32	10.75	7.69	6.82	9.24
1972	10.23	6.28	9.93	6.87	21.63	14.14
1971	8.30	2.89	8.30	0.66	9.80	18.04
1970	5.48	0.26	4.53	0.86	9.34	10.79
1969	9.23	4.44	9.43	4.68	15.84	14.27
1968	9.83	5.80	9.45	5.60	12.48	13.91
1967	8.94	3.24	10.32	4.75	20.17	10.14
1966	6.74	2.25	6.51	3.45	6.92	13.76
1965	9.13	5.50	10.20	6.80	18.29	12.24
1964	9.73	4.89	8.83	4.07	7.41	18.15
1963	7.89	0.50	9.62	2.69	12.68	9.75
1962	9.42	4.82	9.88	6.82	13.53	11.66
1961	9.56	5.46	9.87	3.73	10.66	17.25
1960	8.76	4.09	6.96	3.90	8.07	11.17
1959	9.08	5.45	10.75	6.09	9.25	17.57
1958	9.69	5.27	9.98	5.77	21.48	9.96
1957	9.71	4.31	9.20	3.69	10.65	18.74
1956	4.17	0.25	0.76	0.00	4.73	13.76
1955	5.66	2.03	7.96	4.90	17.74	4.38
Minimum	4.17	0.25	0.76	0.00	4.73	4.38
Maximum	10.51	6.86	10.75	7.69	21.63	18.74
Median	8.9	4.3	8.8	4.1	11.2	13.8
Mean	8.5	4.0	8.4	4.3	12.3	13.0
Variance	2.3	3.0	4.2	3.4	21.7	12.6
CV (%)	17.9	43.4	24.3	42.7	37.9	27.3

Economic Analysis

The yields simulated for each cropping strategy were used to estimate the distribution of returns for that strategy. The strategies were then compared by their distributions of returns.

Production costs and grain prices used to compute returns were obtained mostly from the budgets found in the Farm Management Guides: Flood Irrigated Corn, Flood Irrigated Grain Sorghum, and Flood Irrigated Wheat (Pretzer and Nelson 1986 a, b, and c). Cost budgets are shown in Tables 3, 4, and 5. The budgets do not include annual land costs for two reasons. First, land costs are a function of land values, which in turn, are a function of expected net returns to crop production. Second, the analysis here considers the possibility of shifting from irrigation to dryland production, but typically, budgeted land costs are lower for dryland production. However, to evaluate possible shifts from irrigated to dryland, the land cost must be comparable.

Our budgets had to reflect the cost differences of different levels of irrigation. Therefore, we used certain budget information given in the guide Flood Irrigated Corn (Pretzer and Nelson 1986a). The amount of water shown as applied is the amount available to the crop. The amount of water that must be pumped is obtained by dividing that amount by the irrigation efficiency, which we assumed to be 67 percent. The cost of fuel and oil for pumping, also taken from Pretzer and Nelson (1986a), was $0.93 per acre inch pumped, which is based on a total dynamic pumping head of 200 feet of lift, a pump efficiency of 75 percent, and a natural gas cost of $2.50 per thousand cubic feet.

Because of differences in pumping lifts and in energy costs throughout Southwest Kansas, the energy cost per acre inch of water pumped is quite variable. When available, natural gas usually is the cheapest source of pumping energy in the region, although it's price may range from $.55 to $5.50 per MCF. The high variability in natural gas prices is due to the different contractual arrangements that farmers may have for its acquisition. Some farmers have long-term gas contracts written years ago during the development of the gas fields in the region. Their costs are closer to the low end of the range cited. New natural gas customers in the region are likely to face costs near the top of that range. Other important sources of pumping energy are diesel fuel and electricity. The cost of pumping with diesel fuel is comparable to the cost of using natural gas at $5.50 per MCF. The cost of electricity can exceed the cost of using either natural gas or diesel fuel. Also, pumping lift at many wells may exceed the lift assumed here of 185 feet plus 15 feet for friction losses. Thus, depending on the circumstances, pumping energy costs can be below the budgeted cost or as much as two or three times above it. In some of our analyses, we shall consider that variability.

In Pretzer and Nelson's guides (1986 a, b, and c), the cost of repairs for irrigation equipment is $9 per acre for 16 inches of water applied to the crop or for 24 inches of water pumped when the irrigation efficiency is 67 percent. So, we assumed that the cost of such repairs was $2.25 per acre for each 4 inches applied to the crop.

In a similar fashion, we had to budget for differences in labor based on the amount of water applied. For labor requirement for the nonirrigation part of crop production, we used the labor standards for dryland production in western Kansas as given by Langemeier (1985). We assumed that the labor required per acre for irrigating was 0.10 hours per inch of water applied.

Fertilization rates were specified by the late Mark Hooker and by David Whitney of the KSU Department of Agronomy. Fertilizer prices were taken from Pretzer and Nelson (1986a).

Our budgeted grain prices, obtained from the same budgets as the cost estimates, were $1.60 per bushel for corn, $1.30 per bushel for grain sorghum, and $2.10 per bushel for wheat. Because those prices are low compared to prices during the past decade, we also computed returns for prices at 110, 120, 130, 140, 150, and 160 percent of those base prices. Because short-run decisions should be based on returns after deducting total variable costs, and long-run decisions should be based on returns after deducting totals costs, we computed both.

The cropping strategies were compared in terms of average returns and the standard deviation of returns. Only yield was considered stochastic or risky. True risk involves price risks as well as yield risks, but price risks were not considered here. All analysis was on a per acre basis. No issues of whole farm management were considered.

RESULTS AND DISCUSSION

Validation Tests

Each physiological growth model was evaluated according to how well it could simulate the yields recorded for selected test-plot experiments run at Garden City, Kansas (Tables 6, 7, and 8). As expected, none of the models was able to duplicate exactly the test-plot yields. Statistics to evaluate the extent to which each model simulates test-plot yields are summarized in Table 9.

The number of test-plot trials used to evaluate each model was limited by the availability of trials having sufficient recorded information to permit simulation. We identified a large number of usable trials for corn (114) and wheat (95). Far fewer trials were identified for grain sorghum (39), but those were sufficient to evaluate the model's performance.

A valid model should be able to produce the same range of yields produced in the experimental trials. The range of yields simulated with CERES (corn) was nearly the same as the range of yields harvested from the trials. PHOTO had difficulty simulating a yield as high as the highest actual wheat yield. Even though more times than not, the yields simulated with PHOTO were smaller than the actual yields, the mean simulated yield and the mean actual yield were quite close. SORGF had difficulty simulating yields at either extreme, but it had the greatest difficulty simulating the highest yields. However, because SORGF produced simulated yields that exceeded the actual yield 67 percent of the time, the mean simulated yield was 10 percent higher than

Table 3. Budgets for 10 corn cropping strategies

	Cropping Strategy									
Rates	PP-4	PP-8	Mid-Jul	PP-4+TAS	PP-8+TAS	PP-4+TAS +BEG	PP-8+TAS +BEG	PP-4+TAS +T-B+BEG	CF	CC
Crop labor (hrs./A)	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	2.10	1.85
Irr. labor (hrs./A)	.40	.80	.40	.80	1.20	1.20	1.60	1.60	0.00	0.00
Seed (lbs./A)	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	17.40	17.40
Nitrogen (lbs./A)	30.00	30.00	50.00	100.00	150.00	150.00	180.00	180.00	50.00	30.00
P205 (lbs./A)	0.00	0.00	0.00	0.00	40.00	40.00	40.00	40.00	0.00	0.00
Variable Costs Per Acre:										
Labor	13.50	15.90	13.50	15.90	18.30	18.30	20.70	20.70	12.60	11.10
Seed	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	17.40	17.40
Herbicide & insecticide	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Fertilizer	5.76	5.76	8.16	14.16	29.76	29.76	33.36	33.36	8.16	5.76
Fuel & oil—crop	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	8.75
Fuel & oil—pumping	5.55	11.10	5.55	11.10	16.66	16.66	22.21	22.21	0.00	0.00
Crop machinery repairs	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	12.00
Irrigation equipment repairs	2.25	4.50	2.25	4.50	6.75	6.75	9.00	9.00	0.00	0.00
Miscellaneous	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Interest on working capital	7.03	7.64	7.17	8.15	9.69	9.69	10.52	10.52	6.32	5.88
Total Variable Costs	124.19	135.01	126.74	143.91	171.26	171.26	185.89	185.89	111.58	103.89
Fixed Costs Per Acre (excluding land cost):										
Depreciation expense										
on Crop machinery	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86
on Irrigation equipment	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	0.00	0.00
Interest and insurance										
on Crop machinery	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
on Irrigation equipment	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	0.00	0.00
Total Fixed Costs	55.61	55.61	55.61	55.61	55.61	55.61	55.61	55.61	32.86	32.86
Total Costs	179.80	190.62	182.35	199.52	226.87	226.87	241.50	241.50	144.44	136.75

Table 4. Budgets for 10 sorghum cropping strategies

	Cropping Strategy									
Rates	PP-4	PP-8	Mid-Jul	PP-4+9LF	PP-8+9LF	PP-4+9LF +BT	PP-8+9LF +BT	PP-4+9LF +BT+FL	SF	SS
Crop labor (hrs./A.)	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.80	1.55
Irrigation labor (hrs./A.)	0.40	0.80	0.40	0.80	1.20	1.20	1.60	1.60	0.00	0.00
Seed (lbs./A.)	3.00	3.00	3.00	3.00	3.60	3.60	3.60	3.60	3.00	3.00
Nitrogen (lbs./A.)	60.00	80.00	80.00	100.00	110.00	120.00	120.00	120.00	60.00	30.00
P2O5 (lbs./A.)	30.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	30.00	0.00
Water applied	4.00	8.00	4.00	8.00	12.00	12.00	16.00	16.00	0.00	0.00
Variable Costs Per Acre:										
Labor	11.70	14.10	11.70	14.10	16.50	16.50	18.90	18.90	10.80	9.30
Seed	3.00	3.00	3.00	3.00	3.60	3.60	3.60	3.60	3.00	3.00
Herbicide & insecticide	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75
Fertilizer	15.60	20.40	20.40	22.80	24.00	25.20	25.20	25.20	15.60	3.60
Fuel & oil—crop	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	8.50
Fuel & oil—pumping	5.55	11.10	5.55	11.10	16.66	16.66	22.21	22.21	0.00	0.00
Crop machinery repairs	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	11.00
Irrigation equipment repairs	2.25	4.50	2.25	4.50	6.75	6.75	9.00	9.00	0.00	0.00
Miscellaneous	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Interest on working capital	5.58	6.48	5.87	6.62	7.34	7.41	8.03	8.03	5.06	3.97
Total Variable Costs	98.53	114.43	103.62	116.98	129.70	130.97	141.78	141.78	89.31	70.12
Fixed Costs Per Acre (excluding land cost):										
Depreciation expense										
on Crop machinery	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86
on Irrigation equipment	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	0.00	0.00
Interest & insurance										
on Crop machinery	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
on Irrigation equipment	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	0.00	0.00
Total Fixed Costs	55.61	55.61	55.61	55.61	55.61	55.61	55.61	55.61	32.86	32.86
Total Costs	154.14	170.04	159.23	172.59	185.31	186.58	197.39	197.39	122.17	102.98

Table 5. Budgets for 9 wheat cropping strategies

	Cropping Strategy								
Rates	PP-4	PP-8	PP-4+BT	PP-8+BT	PP-4+BT +SD	PP-8+BT +SD	PP-4+JT +BT+SD	WF	WW
Crop labor (hrs./A.)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.00
Irrigation labor (hrs./A.)	0.40	0.80	0.80	1.20	1.20	1.60	1.60	0.00	0.00
Seed (lbs./A.)	4.80	4.80	4.80	4.80	4.80	4.80	4.80	3.00	3.00
Nitrogen (lbs./A.)	30.00	30.00	50.00	50.00	50.00	50.00	70.00	30.00	30.00
P2O5 (lbs./A.)	0.00	0.00	30.00	30.00	30.00	30.00	30.00	0.00	0.00
Water applied (in.)	4.00	8.00	8.00	12.00	12.00	16.00	16.00	0.00	0.00
Variable Costs Per Acre:									
Labor	8.40	10.80	10.80	13.20	13.20	15.60	15.60	7.50	6.00
Seed	4.80	4.80	4.80	4.80	4.80	4.80	4.80	3.00	3.00
Herbicide & insecticide	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
Fertilizer	7.20	7.20	19.20	19.20	19.20	19.20	24.00	7.20	7.20
Fuel & oil—crop	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	6.00
Fuel & oil—pumping	5.55	11.10	11.10	16.65	16.65	22.20	22.20	0.00	0.00
Crop machinery repairs	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	10.00
Miscellaneous	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Interest on working capital	3.51	4.12	4.84	5.45	5.45	6.06	6.35	2.88	2.52
Total Variable Costs	61.96	72.77	85.49	96.30	96.30	107.11	112.20	50.83	44.47
Fixed Costs Per Acre (excluding land cost):									
Depreciation expense									
on Crop machinery	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86	22.86
on Irrigation equipment	14.00	14.00	14.00	14.00	14.00	14.00	14.00	0.00	0.00
Interest and insurance									
on Crop machinery	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
on Irrigation equipment	8.75	8.75	8.75	8.75	8.75	8.75	8.75	0.00	0.00
Total Fixed Costs	55.61	55.61	55.61	55.61	55.61	55.61	55.61	32.86	32.86
Total Costs	117.57	128.38	141.10	151.91	151.91	162.72	167.81	83.69	77.33

Table 6. Actual and simulated corn yields for selected field trials at Garden City Branch Station, 1974-82

Crop Year	Exp. No.	Planting Date	Plant Pop.	Plant Variety	Crop Mgmt. Practices	Plot Yield	Simulated Yield
						Bu./Acre	
82	1	May 3	25,300	P 3183	PP + 3 irr	109.0	102.7
82	1	May 13	25,300	P 3183	PP + 3 irr	142.0	117.6
82	1	May 23	25,300	P 3183	PP + 3 irr	93.0	116.6
82	1	June 3	25,300	P 3183	PP + 3 irr	76.0	131.3
82	2	May 3	25,300	J 247	PP + 3 irr	84.5	98.2
82	2	May 13	25,300	J 247	PP + 3 irr	106.5	92.4
82	2	May 23	25,300	J 247	PP + 3 irr	67.6	98.7
82	2	June 3	25,300	J 247	PP + 3 irr	72.7	103.4
81	3	Apr 22	25,300	P 3183	PP + 2 irr	139.4	120.3
81	3	May 1	27,000	P 3183	PP + 2 irr	155.5	133.3
81	3	May 7	27,000	P 3183	PP + 2 irr	163.1	135.1
81	3	May 15	27,000	P 3183	PP + 2 irr	154.6	127.5
81	3	May 22	27,000	P 3183	PP + 2 irr	138.6	135.2
81	3	June 3	27,000	P 3183	PP + 2 irr	136.0	159.7
81	4	Apr 22	27,000	P 3186	PP + 2 irr	124.2	110.8
81	4	May 1	27,000	P 3186	PP + 2 irr	136.9	130.7
81	4	May 7	27,000	P 3186	PP + 2 irr	161.4	125.2
81	4	May 15	27,000	P 3186	PP + 2 irr	143.7	121.0
81	4	May 22	27,000	P 3186	PP + 2 irr	128.4	123.6
81	4	June 3	27,000	P 3186	PP + 2 irr	125.9	138.1
81	5	Apr 22	27,000	NB 611	PP + 2 irr	102.2	72.8
81	5	May 1	27,000	NB 611	PP + 2 irr	133.5	74.6
81	5	May 7	27,000	NB 611	PP + 2 irr	130.1	74.5
81	5	May 15	27,000	NB 611	PP + 2 irr	115.8	71.4
81	5	May 22	27,000	NB 611	PP + 2 irr	127.6	85.8
81	5	June 3	27,000	NB 611	PP + 2 irr	136.9	90.0
80	1	Flood	21,000	P 3183	6 irr	88.0	90.4
80	2	Sprinkler	21,000	P 3183	12 irr	112.6	83.8
78	1	May 16	15,900[3]	BJ X56	PP + 1	68.4	96.6
78	1	May 16	19,400	BJ X56	PP + 1	65.0	102.8
78	1	May 16	22,900	BJ X56	PP + 1	61.7	101.7
78	2	May 16	15,800	BJ X56	PP + 2	84.5	99.5
78	2	May 16	19,800	BJ X56	PP + 2	83.7	106.6
78	2	May 16	23,000	BJ X56	PP + 2	83.7	108.8
78	3	May 16	16,100	BJ X56	PP + 2	77.7	100.3
78	3	May 16	19,400	BJ X56	PP + 2	81.1	106.3
78	3	May 16	23,100	BJ X56	PP + 2	80.3	108.8
78	4	May 16	15,900	BJ X56	PP + 4	84.5	99.8
78	4	May 16	20,500	BJ X56	PP + 4	94.6	107.1
78	4	May 16	22,800	BJ X56	PP + 4	86.2	108.6
77	1	May 10	16,100	P 3195A	PP + 1	100.6	118.8
77	1	May 10	19,900	P 3195A	PP + 1	100.6	121.2
77	1	May 10	23,600	P 3195A	PP + 1	100.6	122.5
77	2	May 10	16,300	P 3195A	PP + 2	109.0	119.1
77	2	May 10	20,200	P 3195A	PP + 2	119.1	121.3
77	2	May 10	23,400	P 3195A	PP + 2	111.5	122.8
77	3	May 10	16,600	P 3195A	PP + 3	109.9	119.4
77	3	May 10	19,400	P 3195A	PP + 3	118.3	120.9
77	3	May 10	23,400	P 3195A	PP + 3	122.5	122.8
77	4	May 10	16,200	P 3195A	PP + 4	111.5	118.9
77	4	May 10	19,900	P 3195A	PP + 4	116.6	121.2
77	4	May 10	23,500	P 3195A	PP + 4	119.1	122.8
76	1	May 14	8,200	H KR870	PP	45.6	39.9
76	1	May 14	12,000	H KR870	PP	53.2	39.2
76	1	May 14	15,700	H KR870	PP	42.2	39.1
76	2	May 14	8,300	P 3149	PP	51.6	41.5

Table 6. (cont'd)

Crop Year	Exp. No.	Planting Date	Plant Pop.	Plant Variety	Crop Mgmt. Practices	Plot Yield (Bu./Acre)	Simulated Yield (Bu./Acre)
76	2	May 14	12,100	P 3149	PP	61.7	41.1
76	2	May 14	15,600	P 3149	PP	65.9	40.6
76	3	May 14	9,000	H KR870	Mid-July	51.6	60.8
76	3	May 14	12,100	H KR870	Mid-July	62.5	62.0
76	3	May 14	16,000	H KR870	Mid-July	64.2	61.1
76	4	May 14	8,600	P 3149	Mid-July	54.9	61.8
76	4	May 14	11,800	P 3149	Mid-July	69.3	61.7
76	4	May 14	15,400	P 3149	Mid-July	79.4	61.5
76	5	May 14	12,400	H KR870	PP + 1	83.7	96.7
76	5	May 14	16,000	H KR870	PP + 1	84.5	104.0
76	5	May 14	20,100	H KR870	PP + 1	94.6	98.9
76	6	May 14	12,700	P 3149	PP + 1	90.4	104.4
76	6	May 14	16,100	P 3194	PP + 1	99.7	105.8
76	6	May 14	19,800	P 3194	PP + 1	104.8	100.2
76	7	May 14	16,400	H KR870	PP + 2	105.6	107.8
76	7	May 14	20,200	H KR870	PP + 2	98.0	110.8
76	7	May 14	23,800	H KR870	PP + 2	114.1	111.0
76	8	May 14	16,300	P 3149	PP + 2	114.1	121.6
76	8	May 14	20,200	P 3149	PP + 2	124.2	125.1
76	8	May 14	23,400	P 3149	PP + 2	131.0	125.3
76	9	May 14	20,600	H KR870	PP + 4	137.7	111.0
76	9	May 14	24,500	H KR870	PP + 4	143.7	111.1
76	9	May 14	27,600	H KR870	PP + 4	142.8	111.2
76	10	May 14	20,600	P 3149	PP + 4	143.7	125.3
76	10	May 14	23,900	P 3149	PP + 4	151.3	125.4
76	10	May 14	27,200	P 3149	PP + 4	157.2	125.5
75	1	May 19	8,400	P 3149	pre-plant	65.6	38.7
75	1	May 19	12,000	P 3149	pre-plant	79.6	34.3
75	1	May 19	15,800	P 3149	pre-plant	69.1	36.5
75	2	May 19	8,200	P 3149	pre-plant	72.6	82.4
75	2	May 19	11,900	P 3149	mid-July	74.4	93.9
75	2	May 19	16,100	P 3149	mid-July	89.3	93.0
75	2	May 19	12,100	P 3149	mid-July	112.0	105.5
75	3	May 19	15,700	P 3149	PP + 1 July	114.6	113.0
75	3	May 19	20,100	P 3149	PP + 1 July	113.8	116.4
75	4	May 19	15,800	P 3149	PP + 7/1 & 8/1	136.5	134.9
75	4	May 19	18,500	P 3149	PP + 7/1 & 8/1	134.8	136.7
75	4	May 19	23,100	P 3149	PP + 7/1 & 8/1	151.4	136.8
75	5	May 19	19,900	P 3149	PP + 7/2 & 8/1	148.8	136.8
75	5	May 19	23,100	P 3149	PP + 7/2 & 8/1	154.9	136.8
75	5	May 19	27,700	P 3149	PP + 7/2 & 8/1	152.2	136.7
74	1	May 3	8,400	A RX100	pre-plant	39.4	25.5
74	1	May 3	11,900	A RX100	pre-plant	39.4	23.1
74	1	May 3	15,600	A RX100	pre-plant	40.2	24.5
74	2	May 3	7,800	A RX100	mid-July	49.0	57.5
74	2	May 3	10,700	A RX100	mid-July	51.6	66.1
74	2	May 3	12,300	A RX100	mid-July	63.9	68.3
74	3	May 3	12,500	A RX100	PP + 1 July	60.4	94.5
74	3	May 3	16,100	A RX100	PP + 1 July	58.6	113.0
74	3	May 3	20,100	A RX100	PP + 1 July	62.1	115.3
74	4	May 3	12,400	A RX100	PP + 1 July	90.1	122.3
74	4	May 3	16,200	A RX100	PP + 1 July	84.0	144.4
74	4	May 3	19,900	P 3149	PP + 1 July	83.1	146.1
74	5	May 3	17,000	P 3149	PP + 7/2 & 8/1	108.5	146.9
74	5	May 3	25,800	P 3149	PP + 7/2 & 8/1	91.9	151.3
74	5	May 3	20,100	P 3149	PP + 7/2 & 8/1	103.2	149.4
74	5	May 3	30,000	P 3149	PP + 7/2 & 8/1	95.4	152.7
74	5	May 3	23,300	P 3149	PP + 7/2 & 8/1	100.6	150.5

P = Pioneer BJ = Bo-Jacques J = Jacques NB = Nebraska H = Horizon A = Asgrow

Table 7. Actual and simulated grain sorghum yields for selected field trials at Garden City Branch Station, 1976-83

Crop Year	Exp. No.	Planting Date	Plant Pop.	Hybrid Variety	Crop Mgmt. Practices	Plot Yield Bu./Acre	Simulated Yield Bu./Acre
83	1	May 16	75,000	P 8272	PP only	38	53.8
83	2	May 16	75,000	P 8272	PP + GD	54	112.8
83	3	May 16	75,000	P 8272	PP + boot	52	107.1
83	4	May 16	75,000	P 8272	PP + GD + boot	65	113.5
83	5	May 16	75,000	P 8272	PP + 50% ASW	64	113.5
82	1	June 7	25,000	D 42	WSF notill	66.5	84.1
82	2	June 7	25,000	D 42	SF notill	69.1	81.1
82	3	May 28	75,000	P 8272	PP only	133	115.2
82	4	May 28	75,000	P 8272	PP + 9 leaf	138	115.2
82	5	May 28	75,000	P 8272	PP + boot	146	115.2
82	6	May 28	75,000	P 8272	PP + 9 lf + bt	150	115.2
82	7	May 28	75,000	P 8272	PP + 50% ASW	152	115.2
81	1	June 3	25,000	D C42a+	WSF notill	61.3	52.4
81	2	June 3	25,000	D C42a+	SF notill	73.5	60.8
80	1	June 6	25,000	D C42a+	WSF notill	49.9	65.0
80	2	June 6	25,000	D C42a+	SF notill	51.6	62.2
79	1	June 5	25,000	D C42a+	WSF notill	49.9	91.0
79	2	June 5	25.000	D C42a+	SF notill	56.0	90.3
78	1	May 24	60,000	T 101R	PP only	72	137.9
78	2	May 24	60,000	T 101R	mid-July irr	92	137.9
78	3	May 24	60,000	T 101R	PP + @ 18″	118	137.9
78	4	May 24	60,000	T 101R	PP + @ boot	109	137.9
78	5	May 24	60,000	T 101R	PP + 18″ + boot	125	137.9
78	6	May 24	60,000	T 101R	PP+18″+bt+hd	131	137.9
78	7	May 24	60,000	T 101R	PP + head	111	130.4
78	8	May 24	60,000	T 101R	PP + 50% ASW	130	137.9
77	1	June 2	72,000	T 101	PP only	108	123.4
77	2	June 2	72,000	T 101	mid-July irr	126	123.4
77	3	June 2	72,000	T 101	PP + 15 inch	127	123.4
77	4	June 2	72,000	T 101	PP + boot	123	123.4
77	5	June 2	72,000	T 101	PP + 15″ + bt	134	123.4
77	6	June 2	72,000	T 101	PP+15″+bt+hd	135	123.4
77	7	June 2	72,000	T 101	PP + 50% ASW	124	123.4
76	1	May 28	60,000	T 101	PP only	100	62.2
76	2	May 28	60,000	T 101	mid-July irr	104	131.0
76	3	May 28	60,000	T 101	PP + boot	121	134.4
76	4	May 28	60,000	T 101	PP + 15″ + bt	133	134.4
76	5	May 28	60,000	T 101	PP+15″+bt+fl	123	134.4
76	6	May 28	60,000	T 101	PP + 50% ASW	127	134.4

P = Pioneer D = DeKalb T = TEY

Table 8. Actual and simulated wheat yields for selected field trials at Garden City Branch Station, 1974-83

Crop Year	Exp. No.	Planting Date	Seeding Rate	Variety	Crop Mgmt. Practices	Plot Yield Bu./Acre	Simulated Yield Bu./Acre
83	1	Sept 16	37 lb/A	S	WF no till	46.4	31.5
82	2	Sept 14	40 lb/A	S	WSF no till	41.1	29.1
82	3	Oct 5	60 lb/A	C	PP only	43	41.9
82	3	Oct 5	60 lb/A	N	PP only	48	41.9
82	4	Oct 5	60 lb/A	C	PP + @ joint	58	45.6
82	4	Oct 5	60 lb/A	N	PP + @ joint	60	45.6
82	5	Oct 5	60 lb/A	C	PP + @ flower	50	48.5
82	5	Oct 5	60 lb/A	N	PP + @ flower	57	48.5
82	6	Oct 5	60 lb/A	C	PP + @ jt + @ fl	59	48.5
82	6	Oct 5	60 lb/A	N	PP + @ jt + @ fl	60	48.5
81	1	Sept 17	50 lb/A	S	WF no till	27.1	24.1
81	2	Sept 17	50 lb/A	S	WSF no till	21.0	23.3
81	3	Oct 10	60 lb/A	C	PP	39	32.6
81	3	Oct 10	60 lb/A	N	PP	41	32.6
81	4	Oct 10	60 lb/A	C	PP + @ joint	50	57.3
81	4	Oct 10	60 lb/A	N	PP + @ joint	56	57.3
81	5	Oct 10	60 lb/A	C	PP + @ flower	40	56.9
81	5	Oct 10	60 lb/A	N	PP + @ flower	43	56.9
81	6	Oct 10	60 lb/A	C	PP + @ jt + @ fl	44	63.1
81	6	Oct 10	60 lb/A	N	PP + @ jt + @ fl	49	63.1
80	1	Sept 11	40 lb/A	S	WF no till	38.5	46.5
80	2	Sept 11	40 lb/A	S	WSF no till	34.1	45.6
78	1	Sept 20	90 lb/A	C	PP	62	49.7
78	1	Sept 20	90 lb/A	S	PP	68	49.7
78	1	Sept 20	90 lb/A	N	PP	69	49.7
78	2	Sept 20	90 lb/A	C	PP + @ early veg	64	69.6
78	2	Sept 20	90 lb/A	S	PP + @ early veg	72	69.6
78	2	Sept 20	90 lb/A	N	PP + @ early veg	73	69.6
78	3	Sept 20	90 lb/A	C	PP + @ early boot	66	69.6
78	3	Sept 20	90 lb/A	S	PP + @ early boot	73	69.6
78	3	Sept 20	90 lb/A	N	PP + @ early boot	72	69.6
78	4	Sept 20	90 lb/A	C	PP + @ heading	65	69.6
78	4	Sept 20	90 lb/A	S	PP + @ heading	74	69.6
78	4	Sept 20	90 lb/A	N	PP + @ heading	73	69.6
77	1	Sept 24	90 lb/A	C	PP	63	63.1
77	1	Sept 24	90 lb/A	S	PP	72	63.1
77	1	Sept 24	90 lb/A	St	PP	54	63.1
77	2	Sept 24	90 lb/A	C	PP + 4″ winter	68	63.1
77	2	Sept 24	90 lb/A	S	PP + 4″ winter	77	63.1
77	2	Sept 24	90 lb/A	St	PP + 4″ winter	66	63.1
77	3	Sept 24	90 lb/A	C	PP + 4″ wint + 4″ @ hd	66	63.1
77	3	Sept 24	90 lb/A	S	PP + 4″ wint + 4″ @ hd	74	63.1
77	3	Sept 24	90 lb/A	St	PP + 4″ wint + 4″ @ hd	66	63.1
77	4	Sept 24	90 lb/A	C	PP + 4″ @ heading	61	63.1
77	4	Sept 24	90 lb/A	S	PP + 4″ @ heading	70	63.1
77	4	Sept 24	90 lb/A	St	PP + 4″ @ heading	54	63.1
76	1	Sept 29	80 lb/A	C	PP	50	35.9
76	1	Sept 29	80 lb/A	S	PP	47	35.9
76	1	Sept 29	80 lb/A	St	PP	36	35.9
76	2	Sept 29	80 lb/A	C	PP + 4″ @ winter	52	36.0
76	2	Sept 29	80 lb/A	S	PP + 4″ @ winter	45	36.0
76	2	Sept 29	80 lb/A	St	PP + 4″ @ winter	40	36.0
76	3	Sept 29	80 lb/A	C	PP + 4″ wint + 4″ hd	53	55.5
76	3	Sept 29	80 lb/A	S	PP + 4″ wint + 4″ hd	46	55.5
76	3	Sept 29	80 lb/A	St	PP + 4″ wint + 4″ hd	42	55.5

Table 8. (cont'd)

Crop Year	Exp. No.	Planting Date	Seeding Rate	Variety	Crop Mgmt. Practices	Plot Yield (Bu./Acre)	Simulated Yield (Bu./Acre)
76	4	Sept 29	80 lb/A	C	PP + 4″ @ heading	43	55.0
76	4	Sept 29	80 lb/A	S	PP + 4″ @ heading	46	55.0
76	4	Sept 29	80 lb/A	St	PP + 4″ @ heading	39	55.0
76	5	Sept 29	80 lb/A	C	PP + 8″ @ heading	44	57.0
76	5	Sept 29	80 lb/A	S	PP + 8″ @ heading	44	57.0
76	5	Sept 29	80 lb/A	St	PP + 8″ @ heading	39	57.0
75	1	Sept 30	80 lb/A	C	PP	61	34.6
75	1	Sept 30	80 lb/A	S	PP	69	34.6
75	1	Sept 30	80 lb/A	St	PP	52	34.6
75	2	Sept 30	80 lb/A	C	PP + 4″ @ boot	62	53.8
75	2	Sept 30	80 lb/A	S	PP + 4″ @ boot	70	53.8
75	2	Sept 30	80 lb/A	St	PP + 4″ @ boot	53	53.8
75	3	Sept 30	80 lb/A	C	PP + 8″ @ boot	60	62.3
75	3	Sept 30	80 lb/A	S	PP + 8″ @ boot	66	62.3
75	3	Sept 30	80 lb/A	St	PP + 8″ @ boot	51	62.3
75	4	Sept 30	80 lb/A	C	PP + 4″ @ milk	55	49.5
75	4	Sept 30	80 lb/A	S	PP + 4″ @ milk	66	49.5
75	4	Sept 30	80 lb/A	St	PP + 4″ @ milk	52	49.5
75	5	Sept 30	80 lb/A	C	PP + 8″ @ milk	59	49.5
75	5	Sept 30	80 lb/A	S	PP + 8″ @ milk	66	49.5
75	5	Sept 30	80 lb/A	St	PP + 8″ @ milk	51	49.5
75	6	Sept 30	80 lb/A	C	PP + 4″ @ bt + 4″ mk	61	62.7
75	6	Sept 30	80 lb/A	S	PP + 4″ @ bt + 4″ mk	64	62.7
75	6	Sept 30	80 lb/A	St	PP + 4″ @ bt + 4″ mk	55	62.7
75	7	Sept 30	80 lb/A	C	PP + 4″ @ bt + 8″ @ mk	60	62.7
75	7	Sept 30	80 lb/A	S	PP + 4″ @ bt + 8″ @ mk	69	62.7
75	7	Sept 30	80 lb/A	St	PP + 4″ @ bt + 8″ @ mk	54	62.7
75	8	Sept 30	80 lb/A	C	PP + 8″ @ bt + 4″ @ mk	60	64.7
75	8	Sept 30	80 lb/A	S	PP + 8″ @ bt + 4″ @ mk	66	64.7
75	8	Sept 30	80 lb/A	St	PP + 8″ @ bt + 4″ @ mk	54	64.7
75	9	Sept 30	80 lb/A	C	PP + 8″ @ bt + 8″ @ mk	57	64.7
75	9	Sept 30	80 lb/A	S	PP + 8″ @ bt + 8″ @ mk	61	64.7
75	9	Sept 30	80 lb/A	St	PP + 8″ @ bt + 8″ @ mk	50	64.7
74	1	Oct 5	100 lb/A	C	PP	39	27.5
74	1	Oct 5	100 lb/A	K	PP	30	27.5
74	1	Oct 5	100 lb/A	T	PP	26	27.5
74	2	Oct 5	100 lb/A	C	PP + 4″ @ boot	40	31.6
74	2	Oct 5	100 lb/A	K	PP + 4″ @ boot	32	31.6
74	2	Oct 5	100 lb/A	T	PP + 4″ @ boot	29	31.6
74	3	Oct 5	100 lb/A	C	PP + 6″ @ boot	41	36.9
74	3	Oct 5	100 lb/A	K	PP + 6″ @ boot	30	36.9
74	3	Oct 5	100 lb/A	T	PP + 6″ @ boot	26	36.9

C = Centurk S = Sage St = Sturdy N = Newton

the mean actual yield. For each of the models, the standard deviation of the simulated yields was quite close to the standard deviation of the corresponding experimental yields.

For the last set of tests, we regressed the experimental yields against their corresponding simulated yields. If each simulated yield perfectly reproduced its corresponding experimental yield, the regression results would be as follows: an intercept of zero, a slope coefficient of 1, and a coefficient of determination of 1. Each model was evaluated on how close the regression results were to those ideal results. Because the test-plot trials were designed to control other factors that affect yield, it was not possible to obtain complete control. For example, insect and other pest infestations, weed problems, severe wind, and hail can all decrease yields. Because in most cases all the trials run in a given year for a specific crop were in close proximity to each other, we suspect that most of those other factors tended to be constant over trials run the same year but varied over years. We removed such year effects in a second set of regressions by adding dummy variables for the years. Because adding the dummy variables produces a different intercept for each year, it is not important to look at the intercept estimate. Rather, our interest is in the slope coefficient and the coefficient of determination-both of which, ideally, should have a value of 1.

The results of the regression analysis are also shown on Table 9. The results for all three models were quite similar when regressing actual yield against simulated yield only. The slope coefficients ranged from .68 to .84, which is fairly near to 1. The coefficient of determination ranged from .43 to .48, which means that from 43 to 48 percent of the variation was explained by the regression. The regression equation that accounted for year effects produced coefficients of determination ranging from .72 to .79 and slope coefficients ranging from .21 to .79. The larger coefficients of determination are favorable, but the smaller slope coefficients are not. Of particular concern is the much lower slope coefficient value for the regression with PHOTO's simulations. We have no good explanation for this result.

Our conclusion is that all three models do a reasonable job of simulating yields, but future enhancements to improve each model's ability to predict yields are needed. Two concerns merit special attention. First is the tendency of SORGF to overpredict. The mean simulated yield was 10 percent greater than the mean harvested yield. The second concern is PHOTO's apparent lack of sensitivity, as reflected in the small slope coefficient when year effects were included.

Simulations

The simulated yields for each cropping strategy are shown in Tables 10, 11 and 12. For each strategy, a yield was simulated for each year in which we had weather data. The set of simulated yields for each strategy is followed by the mean, maximum, and minimum yields; standard deviation; and the coefficient of variation for the simulated yields.

The results show that there were considerable year-to-year differences in yields for any strategy. These were caused mainly by the large yearly variations in weather, particularly precipitation. When precipitation during the growing season was low, the simulated yields varied considerably among cropping strategies. However, those differences disappeared with a high level of precipitation during the growing season. Compared to the continuous cropping strategy, the other strategies differed either in the amount and timing of water applied (irrigations) or in initial soil moisture (fallow). As precipitation during the growing season increased, the impact of irrigations or of stored soil moisture declined.

As more irrigation water was applied, the mean yield tended to increase and the coefficient of variation decreased, but the variance of the yields did not always decrease. For corn, the variance was inversely related to the amount of water applied and was highest with one mid-July irrigation. The corn-fallow, preplant irrigation only, and the mid-July irrigation strategies all produced yields varying more than that for continuous dryland corn.

For grain sorghum, the variance was also inversely related to the amount of water applied and was highest for the strategy of applying 4 inches of water before planting. Continuous dryland sorghum had a higher variance than any of the irrigation strategies or the grain sorghum-fallow strategy.

For wheat, the variance was lowest with continuous wheat, nearly twice as large for wheat fallow, and slightly higher still for the irrigation strategies.

Table 9. Results of validation tests for three models

	CERES (corn)		PHOTO (wheat)		SORGF (grain sorghum)	
Item	Experiments	Simulations	Experiments	Simulations	Experiments	Simulations
Number of observations	114	114	97	97	39	39
Range of yields, Bu./A.	151.5	153.3	56.0	46.3	114.0	85.5
Minimum yield, Bu./A.	11.6	6.3	21.0	23.3	38.0	52.4
Maximum yield, Bu./A.	163.1	159.7	77.0	69.6	152.0	137.9
Mean yield, Bu./A.	99.7	188.7	53.5	52.8	181.1	111.6
Standard deviation	33.2	34.4	13.2	13.1	34.3	26.7

	CERES	PHOTO	SORGF
Frequency simulated yield greater than experimental yield	51%	41%	66%
Experimental yield regressed on simulated yield			
Intercept	38.83	17.25	7.16
Slope coefficient	0.68	0.78	0.84
R squared	0.45	0.48	0.43
Experimental yield regressed on simulated yield with year effects			
Slope coefficient	0.65	0.21	0.88
R squared	0.77	0.79	0.72

Table 10. Simulated corn yields (bu./acre) by cropping strategies

	Cropping Strategy									
Year	PP-4	PP-8	Mid-Jul	PP-4+TAS	PP-8+TAS	PP-4+TAS +BEG	PP-8+TAS +BEG	PP-4+TAS +T-B+BEG	CF	CC
1983	12.2	17.5	13.6	18.9	24.1	76.8	79.9	80.2	15.1	6.6
1982	78.2	112.2	110.1	90.0	116.0	117.7	117.7	117.7	101.2	31.1
1981	84.2	102.6	117.7	126.7	135.1	135.1	135.1	135.1	98.5	43.9
1980	17.1	20.9	38.0	30.6	36.9	100.6	101.7	103.1	19.8	11.8
1979	56.8	75.4	101.0	95.9	127.7	127.7	127.7	127.7	66.2	31.9
1978	45.6	45.7	63.5	56.3	56.3	120.0	120.0	131.6	45.7	40.4
1977	64.4	66.5	124.0	97.7	97.5	127.8	127.8	127.9	66.5	59.8
1976	27.0	34.7	35.8	47.8	52.4	96.2	107.6	117.3	32.7	16.5
1975	33.5	41.2	53.7	48.4	50.0	102.5	102.7	126.7	39.6	22.4
1974	44.3	49.5	62.7	68.1	69.1	137.5	137.8	160.8	47.1	31.0
1973	25.9	32.8	53.4	48.8	67.5	106.3	121.5	148.0	28.2	14.7
1972	163.0	163.0	163.0	163.0	163.0	163.0	163.0	163.0	163.0	163.0
1971	29.4	43.3	43.2	58.6	68.8	120.7	139.8	140.0	43.5	14.7
1970	22.6	37.8	28.3	42.2	57.4	96.8	105.0	105.7	34.9	9.7
1969	71.1	96.9	106.0	119.0	121.0	130.0	130.0	130.0	96.3	31.5
1968	33.2	41.3	67.6	88.3	88.5	130.1	130.1	130.2	38.8	23.0
1967	167.4	167.4	167.4	167.4	167.4	167.4	167.4	167.4	167.4	150.3
1966	12.4	30.9	6.7	37.2	69.6	116.8	120.2	120.7	26.1	3.6
1965	106.9	118.6	143.6	118.7	118.7	143.5	143.5	143.6	117.0	92.5
1964	15.9	21.2	36.5	30.2	34.0	77.9	80.1	89.1	20.1	10.0
1963	55.0	73.0	67.0	85.3	86.1	105.4	105.4	105.4	57.3	41.3
1962	66.4	81.9	91.1	105.3	108.0	108.0	108.0	108.0	78.1	44.0
1961	33.8	52.8	80.8	74.6	76.9	105.4	105.4	105.4	42.3	17.6
1960	18.2	22.9	32.1	37.3	41.8	80.8	84.3	107.1	21.7	11.7
1959	26.9	38.4	68.2	65.0	84.0	100.1	100.2	100.2	30.8	16.9
1958	116.2	116.2	116.2	116.2	116.2	116.2	116.2	116.2	116.2	116.2
1957	33.1	47.5	44.6	47.2	50.4	97.8	100.8	111.0	49.4	16.5
1956	2.7	7.5	10.4	6.6	15.6	43.3	66.0	79.8	3.6	0.1
1955	43.4	48.2	78.2	70.6	70.8	101.8	101.8	102.0	47.9	38.9
Minimum	2.7	7.5	6.7	6.6	15.6	43.3	66.0	79.8	3.6	0.1
Maximum	167.4	167.4	167.4	167.4	167.4	167.4	167.4	167.4	167.4	163.0
Median	33.8	47.5	67.0	68.1	70.8	108.0	116.2	117.7	45.7	23.0
Mean	52.0	62.3	73.3	74.5	81.8	112.2	115.4	120.7	59.1	38.3
Variance	1763.3	1757.5	1939.8	1653.3	1559.6	663.7	549.4	515.2	1778.0	1713.1
CV	80.8	67.3	60.1	54.5	48.3	23.0	20.3	18.8	71.3	108.0

Table 11. Simulated sorghum yields (bu./acre) by cropping strategy

	Cropping Strategy									
Year	PP-4	PP-8	Mid-Jul	PP-4+9LF	PP-8+9LF	PP-4+9LF +BT	PP-8+9LF +BT	PP-4+9LF +BT+FL	SF	SS
1983	19.5	54.4	34.6	61.0	61.0	115.0	115.0	115.1	31.7	9.6
1982	113.8	113.8	113.9	113.8	113.8	113.8	113.8	113.8	107.8	64.7
1981	115.0	120.2	120.3	120.2	120.2	120.2	120.2	120.2	112.9	75.8
1980	47.2	70.9	70.5	92.6	92.6	125.2	125.2	125.2	54.6	32.1
1979	107.0	121.3	121.3	121.3	121.3	121.3	121.3	121.3	111.9	75.7
1978	104.6	104.6	127.6	113.8	113.8	127.6	127.6	127.6	107.7	101.7
1977	113.5	117.9	118.0	117.9	117.9	117.9	117.9	117.9	111.5	78.2
1976	24.9	60.7	48.2	59.2	96.1	125.7	126.8	126.8	30.8	12.7
1975	53.5	86.9	80.2	92.2	92.2	128.0	128.0	128.0	71.4	24.0
1974	81.3	81.3	109.7	107.1	107.1	119.5	119.5	119.5	88.3	46.7
1973	51.4	90.0	93.3	118.1	118.1	142.6	142.5	142.6	60.1	27.1
1972	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	106.1	106.1
1971	62.4	104.5	100.9	99.7	141.3	143.5	143.5	143.5	74.1	38.0
1970	58.7	106.0	106.0	101.6	117.1	117.2	117.1	117.2	53.5	38.7
1969	95.0	106.2	106.3	106.2	106.2	106.2	106.2	106.2	99.9	46.1
1968	105.7	105.7	112.4	112.1	112.1	112.4	112.4	112.4	102.2	58.4
1967	108.9	108.9	109.1	108.9	108.9	108.9	108.9	108.9	103.0	103.1
1966	53.4	79.5	94.1	78.6	111.2	111.3	111.2	111.3	50.7	32.1
1965	119.4	119.4	119.6	119.4	119.4	119.6	119.6	119.6	113.2	113.2
1964	19.3	39.9	41.0	65.9	73.7	107.4	107.4	104.4	36.6	10.4
1963	45.9	106.9	96.8	107.1	118.6	118.6	118.6	118.6	100.9	18.9
1962	120.1	135.7	135.4	135.7	135.7	135.7	135.7	135.7	126.6	72.9
1961	105.7	111.4	111.7	111.4	111.4	111.4	111.4	111.4	105.1	56.8
1960	42.7	62.0	68.4	79.4	79.4	117.9	117.9	118.9	72.2	20.2
1959	87.2	107.0	111.6	116.2	116.2	116.2	116.2	116.2	83.1	34.2
1958	121.2	121.2	121.2	121.2	121.2	121.2	121.2	121.2	114.8	114.8
1957	47.4	80.3	71.9	85.7	85.7	118.3	118.3	118.3	83.9	19.0
1956	11.4	35.2	0.0*	33.4	95.5	108.1	119.0	119.1	11.0	0.0*
1955	90.7	90.7	113.7	102.2	102.2	121.0	121.0	121.0	92.3	42.9
Minimum	11.4	35.2	0.0	33.4	61.0	106.2	106.2	104.6	11.0	0.0
Maximum	121.2	135.4	135.7	135.7	141.3	143.5	143.5	143.5	126.6	114.8
Median	87.2	105.7	109.1	107.1	112.1	118.3	118.6	118.9	92.3	42.9
Mean	77.2	95.0	95.6	100.5	107.7	119.4	119.8	119.8	83.4	50.8
Variance	1278.8	663.8	1012.8	531.4	307.6	88.2	84.0	86.8	941.7	1147.8
CV (%)	46.3	27.1	33.3	22.9	16.3	7.9	7.7	7.8	36.8	66.7

*Model did not complete run because available water was too low to allow crop establishment.

Table 12. Simulated wheat yields (bu./acre) by cropping strategy

	Cropping Strategy								
Year	PP-4	PP-8	PP-4+BT	PP-8+BT	PP-4+BT +SD	PP-8+BT +SD	PP-4+JT +BT+SD	WF	WW
1983	55.6	58.6	68.3	69.7	68.4	69.7	69.7	50.5	37.1
1982	28.5	29.2	45.7	48.0	45.8	48.1	58.1	28.5	22.2
1981	28.3	30.3	41.7	43.7	42.4	43.7	52.2	27.5	21.0
1980	43.2	47.8	48.9	49.0	48.9	49.0	49.0	38.7	29.3
1979	25.2	27.5	45.1	49.0	45.7	49.7	58.2	22.5	17.4
1978	40.7	44.0	62.2	64.0	62.5	64.2	65.4	47.9	31.3
1977	61.1	61.5	61.5	61.5	61.5	61.5	61.5	49.8	47.3
1976	30.5	32.4	43.8	46.0	44.3	46.6	57.1	30.0	24.5
1975	32.5	34.1	53.8	56.4	54.1	56.6	63.1	26.9	21.2
1974	29.2	29.2	39.2	39.2	39.7	39.7	49.4	28.1	25.1
1973	29.0	29.0	46.1	46.1	46.6	46.6	64.2	24.4	24.3
1972	38.4	41.3	50.8	54.3	51.3	54.7	61.2	46.4	33.0
1971	16.9	18.7	32.2	33.8	32.6	34.2	37.0	16.6	12.9
1970	18.2	18.2	26.8	26.8	27.2	27.2	34.0	16.4	15.7
1969	30.0	41.4	56.9	65.3	57.4	65.7	74.4	43.1	22.0
1968	24.7	26.0	35.6	36.8	36.2	37.3	44.7	27.4	18.6
1967	29.1	30.2	45.7	47.4	45.9	47.6	50.2	28.5	24.3
1966	29.0	29.0	30.9	30.9	31.2	31.2	35.0	28.1	28.1
1965	46.9	49.5	62.0	64.2	62.0	64.2	66.1	48.8	36.7
1964	21.2	21.6	35.2	36.1	35.8	36.6	39.8	22.1	14.1
1963	23.1	23.1	39.4	39.4	40.3	40.3	44.9	22.2	19.4
1962	20.9	20.9	37.4	37.4	37.8	37.8	48.4	20.0	17.1
1961	25.8	27.5	36.0	37.9	36.6	38.4	47.3	23.2	19.6
1960	29.0	29.0	47.2	47.2	47.2	47.2	61.2	27.8	27.8
1959	26.1	27.0	37.3	38.3	37.8	39.9	46.1	27.1	20.5
1958	53.6	53.6	54.9	54.9	54.9	54.9	54.9	41.3	34.8
1957	30.9	34.2	49.0	54.2	49.7	54.8	64.3	19.7	18.7
1956	15.8	16.4	17.3	18.0	17.5	18.1	22.9	14.6	13.0
Minimum	15.8	16.4	17.3	18.0	17.5	18.1	22.9	14.6	12.9
Maximum	61.1	61.5	68.3	69.7	68.4	69.7	74.4	50.5	47.3
Median	29.0	29.2	45.4	46.7	45.8	46.9	53.6	27.7	22.1
Mean	31.6	33.3	44.7	46.3	45.0	46.6	52.9	30.3	24.2
Variance	132.4	146.5	137.3	154.9	135.1	152.3	148.1	120.0	67.5
CV (%)	36.5	36.4	26.2	26.9	25.8	26.5	23.0	36.2	34.0

Analysis of Net Returns

Net return is gross return (output times price) less the cost of production. The measure of net return used here does not include the interest on the investment in land because that depends on the price or value of the land, which is itself determined, in part, by the economic rent—the revenue remaining after all other costs have been paid.

To evaluate the cropping strategies, we first compared the average and standard deviations of simulated returns among strategies. Those two measures were computed from the crop budgets and from the average and standard deviations of the simulated yields for a strategy. The average return is a measure of expected return, whereas the standard deviation of the return is a measure of the economic risk stemming from the production risk associated with the cropping strategy.

Average returns at various output price levels for each cropping strategy for corn, grain sorghum, and wheat production are shown in Tables 13, 14, and 15, respectively. A range of output prices was used because recent market prices on which our budgeted prices are based were much below the average of prices since 1977.

Returns to corn production were negative for all strategies until the price of corn was increased 30 percent over the base to $2.08/bushel. Then, the three-irrigation strategy and the four-irrigation strategy had positive average returns. At corn prices above $2.08/bushel, the four-irrigation strategy had the highest average return.

Returns to grain sorghum production were negative for all strategies until the price of grain sorghum was increased 20 percent over the base to $1.56/bushel. Then sorghum-fallow strategy had positive average net returns. Sorghum fallow had the highest average net return at that price and at the next price level, but at still higher prices, applying three 4-inch irrigations produced highest average net return. At the highest price level considered, three other strategies had average returns near those of the most profitable strategies. Compared with corn, sorghum has more strategies that might be competitive, depending upon the costs and yields for a particular farm. Also, full irrigation is not required to obtain the highest average net return.

Returns to wheat production were negative for all strategies until the price of wheat was increased 40 percent to $2.94/bushel. Then only the wheat-fallow strategy had a positive average net return. That same strategy had the highest average net return at the next two price levels, too.

To compare returns between crops, we started with corn and grain sorghum at their budgeted or base prices and then at prices for percentage intervals above the base prices. Only when prices increased 50 or 60 percent above the base prices did a corn strategy have higher average net returns than the highest return sorghum strategy. However, our validation tests found that the yields simulated by SORGF averaged about 10 percent above the actual yields. That overestimation can be accounted for by reducing the price of grain sorghum by 10 percent. For example, compare strategies with corn priced at 150 percent of its base and grain sorghum at 140 percent of its base. Then, corn had a higher return when its price was at or above 120 percent of its base. The relative closeness between the returns for the two crops would indicate that at higher prices, the two are relatively competitive with each other. Note, however, that grain sorghum required less applied water.

At the prices used, the wheat strategies generally produced negative returns and returns below those for the corn and grain sorghum strategies. However, a comparison of wheat and corn prices for the past 10 years indicated that the price of wheat used was low relative to the price of corn by about 10 percent. If the price of wheat relative to that of corn were to increase 10 percent, still no wheat strategy would be competitive.

Another consideration is the effect on risk of returns because of yield risks. Two measures useful for evaluating such risk are the standard deviation of the returns and the shape of the distribution (skewness) of returns. When yield is the only random variable in the determination of net returns, the standard deviation of the returns equals the standard deviation of the yield times the price of the output, and the shape of the returns distribution is identical to the shape of the yield distribution. (Note: the simulated returns for the base prices are given in the Appendix, Tables 2 through 4.)

The corn strategy with the highest return had a standard deviation of about $33 per acre. The irrigated sorghum strategies with the higher returns had a much smaller standard deviation of about $11 per acre. Sorghum-fallow had a much larger standard deviation of $34 per acre. Irrigated grain sorghum had a much lower risk of return than either irrigated corn or sorghum-fallow. The standard deviation for the irrigated wheat strategies ranged from $24 to $26 per acre, which was about three-fourths of that for irrigated corn but double that for irrigated grain sorghum.

When a distribution is skewed to the right, there is more weight in the left side of the distribution than in the right side, and the average exceeds the median, so a value of at least the size of the mean will occur less than half the time. A skewness to the left is just the opposite. Among the strategies previously identified as having higher returns, the irrigated corn, the wheat-fallow, and the sorghum fallow strategies had distributions of returns that were skewed to the right, i.e., a return at least as large as the mean occurred less than half the time. For the other strategies, the distribution was skewed somewhat to the left, i.e., a return at least as large as the mean occurred a little more than half the time.

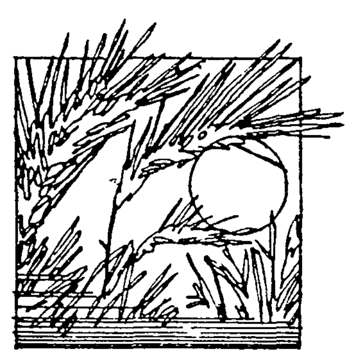


Table 13. Average returns ($) for corn cropping strategies (including returns to land)

	Cropping Strategy									
Variable	PP-4	PP-8	Mid-Jul	PP-4+TAS	PP-8+TAS	PP-4+TAS +BEG	PP-8+TAS +BEG	PP-4+TAS +T-B+BEG	CF	CC
Total variable costs	124.19	135.01	126.74	143.91	171.26	171.26	185.89	185.89	111.58	103.89
Total fixed costs	55.61	55.61	55.61	55.61	55.61	55.61	55.61	55.61	32.86	32.86
Total costs	179.80	190.62	182.35	199.52	226.87	226.87	241.50	241.50	144.44	136.75
Avg. yield	52.00	62.30	73.30	74.50	81.80	112.20	115.40	120.70	59.10	38.30
Avg. gross-TVC	-40.99	-35.33	-9.46	-24.71	-40.38	8.26	-1.25	7.23	-17.02	-42.61
Avg. gross-TC	-96.60	-90.94	-65.07	-80.32	-95.99	-47.35	-56.86	-48.38	-49.88	-75.47
GROSS-TVC										
price @110% ($1.76/bu)	-32.67	-25.36	2.27	-12.79	-27.29	26.21	17.21	26.54	-7.56	-36.48
price @120% ($1.92/bu)	-24.35	-15.39	14.00	-0.87	-14.20	44.16	35.68	45.85	-1.89	-30.35
price @130% ($2.08/bu)	-16.03	-5.43	25.72	11.05	-1.12	62.12	54.14	65.17	11.35	-24.23
price @140% ($2.24/bu)	-7.71	4.54	37.45	22.97	11.97	80.07	72.61	84.48	20.80	-18.10
price @150% ($2.40/bu)	0.61	14.51	49.18	34.89	25.06	98.02	91.07	103.79	30.26	-11.97
price @160% ($2.56/bu)	8.93	24.48	60.91	46.81	38.15	115.97	109.53	123.10	39.72	-5.84
GROSS-TC										
price @110% ($1.76/bu)	-88.28	-80.97	-53.34	-68.40	-82.90	-29.40	-38.40	-29.07	-40.42	-69.34
price @120% ($1.92/bu)	-79.96	-71.00	-41.61	-56.48	-69.81	-11.45	-19.93	-9.76	-30.97	-63.21
price @130% ($2.08/bu)	-71.64	-61.04	-29.89	-44.56	-56.73	6.51	-1.47	9.56	-21.51	-57.09
price @140% ($2.24/bu)	-63.32	-51.07	-18.16	-32.64	-43.64	24.46	17.00	28.87	-12.06	-50.96
price @150% ($2.40/bu)	-55.00	-41.10	-6.43	-20.72	-30.55	42.41	35.46	48.18	-2.60	-44.83
price @160% ($2.56/bu)	-46.68	-31.13	5.30	-8.80	-17.46	60.36	53.92	67.49	6.86	-38.70

Table 14. Average returns ($) for grain sorghum strategies (including returns to land)

	Cropping Strategy									
Variable	PP-4	PP-8	Mid-Jul	PP-4+9LF	PP-8+9LF	PP-4+9LF +BT	PP-8+9LF +BT	PP-4+9LF +BT+FL	SF	SS
Total variable costs	98.53	114.43	103.62	116.98	129.70	130.97	141.78	141.78	89.31	70.12
Total fixed costs	55.61	55.61	55.61	55.61	55.61	55.61	55.61	55.61	32.86	32.86
Total costs	154.14	170.04	159.23	172.59	185.31	186.58	197.39	197.39	122.17	102.98
Avg. yield	77.20	95.00	95.60	100.50	107.70	119.40	119.80	119.80	83.40	50.80
Avg. gross-TVC	-3.50	9.07	20.66	13.67	10.31	24.25	13.96	13.96	19.11	-4.08
Avg. gross-TC	-60.32	-52.65	-42.57	-48.54	-52.14	-40.59	-48.98	-49.06	-22.62	-48.18
GROSS-TVC										
price @110% ($1.43/bu)	11.87	21.42	33.09	26.74	24.31	39.77	29.53	29.53	29.95	2.52
price @120% ($1.56/bu)	21.90	33.77	45.52	39.80	38.31	55.29	45.11	45.11	40.79	9.13
price @130% ($1.69/bu)	31.94	46.12	57.94	52.87	52.31	70.82	60.68	60.68	51.64	15.73
price @140% ($1.82/bu)	41.97	58.47	70.37	65.93	66.31	86.34	76.26	76.26	62.48	22.34
price @150% ($1.95/bu)	52.01	70.82	82.80	79.00	80.32	101.86	91.83	91.83	73.32	28.94
price @160% ($2.08/bu)	62.05	83.17	95.23	92.06	94.32	117.38	107.40	107.40	84.16	35.54
GROSS-TC										
price @110% ($1.43/bu)	-43.74	-34.19	-22.52	-28.88	-31.30	-15.84	-26.08	-26.08	-2.91	-30.34
price @120% ($1.56/bu)	-33.71	-21.84	-10.09	-15.81	-17.30	-0.32	-10.50	-10.50	7.93	-23.73
price @130% ($1.69/bu)	-23.67	-9.49	2.33	-2.74	-3.30	15.21	5.07	5.07	18.78	-17.13
price @140% ($1.82/bu)	-13.64	2.86	14.76	10.32	10.70	30.73	20.65	20.65	29.62	-10.52
price @150% ($1.95/bu)	-3.60	15.21	27.19	23.39	24.71	46.25	36.22	36.22	40.46	-3.92
price @160% ($2.08/bu)	6.44	27.56	39.62	36.45	38.71	61.77	51.79	51.79	51.30	2.68

Table 15. Average returns ($) for wheat cropping strategies (including returns to land)

	Cropping Strategy								
Variable	PP-4	PP-8	PP-4+BT	PP-8+BT	PP-4+BT +SD	PP-8+BT +SD	PP-4+JT +BT+SD	WF	WW
Total variable costs	61.96	72.77	85.49	96.30	96.30	107.11	112.20	50.83	44.47
Total fixed costs	55.61	55.61	55.61	55.61	55.61	55.61	55.61	32.86	32.86
Total costs	117.57	128.38	141.10	151.91	151.91	162.72	167.81	83.69	77.33
Avg. yield	31.60	33.30	44.70	46.30	45.00	46.60	52.90	30.30	24.20
Avg. gross-TVC	4.40	-2.84	8.38	0.93	-1.80	-9.25	-1.11	12.80	6.35
Avg. gross-TC	-51.21	-58.45	-47.23	-54.68	-57.41	-64.86	-56.72	-20.06	-26.51
GROSS-TVC									
price @110% ($2.31/bu)	11.04	4.15	17.77	10.65	7.65	0.54	10.00	19.16	11.43
price @120% ($2.52/bu)	17.67	11.15	27.15	20.38	17.10	10.32	21.11	25.53	16.51
price @130% ($2.73/bu)	24.31	18.14	36.54	30.10	26.55	20.11	32.22	31.89	21.60
price @140% ($2.94/bu)	30.94	25.13	45.93	39.82	36.00	29.89	43.33	38.25	26.68
price @150% ($3.15/bu)	37.28	32.15	55.32	49.55	45.45	39.68	54.44	44.62	31.76
price @160% ($3.36/bu)	44.22	39.12	64.70	59.27	54.90	49.47	65.54	50.98	36.84
GROSS-TC									
price @110% ($2.31/bu)	-44.57	-51.46	-37.84	-44.96	-47.96	-55.07	-45.61	-13.70	-21.43
price @120% ($2.52/bu)	-37.94	-44.46	-28.46	-35.23	-38.51	-45.29	-34.50	-7.33	-16.35
price @130% ($2.73/bu)	-31.30	-37.47	-19.07	-25.51	-29.06	-35.50	-23.39	-0.97	-11.26
price @140% ($2.94/bu)	-24.67	-30.48	-9.68	-15.79	-19.61	-25.72	-12.28	5.39	-6.18
price @150% ($3.15/bu)	-18.03	-23.49	-0.29	-6.07	-10.16	-15.93	-1.18	11.76	-1.10
price @160% ($3.36/bu)	-11.39	-16.49	9.09	3.66	-0.71	-6.14	9.93	18.12	3.98

Shifts in Cropping Strategies

Next, we will consider how well our results reconcile with the adjustments in cropping patterns that occurred between 1977 and 1985 in Southwest Kansas. The adjustments were mostly of two types: a shift from dryland wheat to dryland grain sorghum and a shift from irrigated corn to irrigated sorghum and irrigated wheat. Grain prices rose during the first part of the period and then declined slightly. From 1980 to 1985, corn and grain sorghum prices averaged 157 percent of our base price and wheat price averaged 166 percent of our base price.

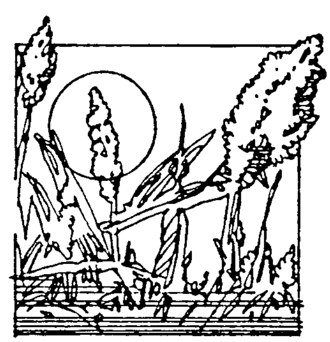
Because the return to sorghum-fallow when sorghum is at $1.69 per bushel (or 140 percent of base price) exceeds the returns to wheat-fallow when wheat is at $3.36 per bushel (or 160 percent of base price), it is reasonable to expect a shift from wheat-fallow to sorghum-fallow, even after allowing for the fact that SORGF appears to be biased upward and that wheat was relatively higher priced than were the feed grains.

Several considerations may enter into the transition from irrigated corn to irrigated grain sorghum and irrigated wheat. When making comparisons among the three strategies with grain prices at 160 percent of the base price, we found that full irrigation of corn gave the highest return, followed by grain sorghum and wheat. However, irrigation costs and groundwater availability vary over the region. If well yield is low or pumping lift is high, so that the amount of water that can be applied is limited, then sorghum would be the crop of choice according to the result obtained here. With total water applied of 4 or 8 or 12 inches, grain sorghum had the highest return even after adjusting for the apparent biasness of SORGF.

With the cost of energy for pumping at three times the cost in the budget and grain prices at 160 percent of their base prices, the highest returns were obtained from full-irrigated corn. Slightly lower returns were received from a single mid-July irrigation of grain sorghum after adjusting for the biasness of SORGF, but no irrigated wheat strategy had a positive return.

With current price conditions (at base prices), no cropping strategy produces enough income to cover total costs excluding land costs. In the long run and with no government payment tied to production, there would be no incentive to continue production. However, in the short-run, the fixed costs will be incurred whether producing a crop or not. In that case, one could attempt to operate so long as income pays for variable costs. The strategy to apply three irrigations to grain sorghum has a return over variable costs of $24.25, the mid-July irrigation strategy has a return over variable costs of $20.66, and the strategy to apply two irrigations to wheat has a return over variable costs of $8.38. The returns over variable costs are $12.80 for wheat-fallow and $19.11 for grain sorghum-fallow.

A farmer who has a wheat or feed grain base would find it advantageous to enroll in the appropriate government programs. If the proven yield for irrigated land is higher than the proven yield for dryland production, it might be profitable to still irrigate in order to qualify for payments based on irrigated production. Otherwise, there does not appear to be any benefit to irrigating at these prices. A strategy not considered that might have a higher return would be to irrigate based on soil moisture levels. Another possibility would be grain sorghum with a mid-July irrigation and a follow-up irrigation when needed to meet a yield goal, e.g., 100 bushels per acre.



CONCLUSIONS

*The range of yields simulated for corn with CERES was nearly the same as the range of actual yields.

*SORGF simulated yields for grain sorghum that exceeded actual yields 67 percent of the time.

*The yields simulated for wheat by PHOTO were often smaller than actual yields, but the means of simulated and actual yields were quite close.

*There were considerable year-to-year differences in yield for any cropping strategy, mainly caused by yearly variations in weather, particularly precipitation.

*When the price of corn was increased to $2.08/bushel, the strategy of irrigating four times a year had a positive return.

*When the price of grain sorghum was increased to $1.69/bushel, two strategies had positive returns: sorghum-fallow and irrigating three times.

*When wheat price was increased to $2.73/bushel, the wheat-fallow strategy had a slightly positive return. At prices of $3.15 and $3.36/bushel, highest returns were obtained from irrigating four times.

*Changing availability of ground water can affect the choice of strategy. With limited water, irrigated wheat and grain sorghum would have higher returns than irrigated corn.

*If the prices of all three commodities were 160 percent of the base price (corn $2.56/bu.; grain sorghum, $2.08/bu.; and wheat, $3.36/bu.) and with the energy cost to irrigate at triple the base rate, the highest return would be with full-irrigated corn followed by grain sorghum with one irrigation in mid-July.

*When deciding whether or not to discontinue irrigating, one must consider the difference in deficiency payment on irrigated versus dryland production.

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Appendix Table 1. Inputs required for growth models

I. INPUT DATA FOR CORN SIMULATION MODEL

Crop data

- Genetic data for Pioneer 3183
- Planting date–May 10
- Planting population–25,000 plants/A
- Seeding depth–1.75 inches

Meteorological data (daily)

- Precipitation, minimum and maximum temperature, solar radiation, and vapor pressure

Soil data

- Initial available soil moisture–See text
- Stage 1 evaporation, upper limit, (U)–.47 in
- Lower limit volumetric fraction by layer–5.9 in–.16; 5.9 in–.16; 11.8 in–.18, 11.8 in–.17; 11.8 in–.17; 11.8 in–.16; 11.8 in–.16
- Drained upper limit by layer–5.9 in–.34; 5.9 in–.34; 11.8 in–.36, 11.8 in–.36, 11.8 in–.36; 11.8 in–.33; 11.8 in–.34
- Saturated soil content by layer–5.9 in–.39; 5.9 in–.39; 11.8 in–.40, 11.8 in–.40; 11.8 in–.39; 11.8 in–.39
- Initial total soil moisture–See text
- Root growth weighting factor–5.9 in–1.00; 5.9 in–.80; 11.8 in–.40; 11.8 in–.30; 11.8 in–.10, 11.8 in–.05
- Bare soil albedo–.18
- Soil water constant for calculating drainage rate per day–.65
- Curve input used to calculate daily runoff–76.00

Irrigation data

- Dates and amounts

II. INPUT DATA FOR GRAIN SORGHUM SIMULATION MODEL

Crop data

Leaf number–total number of leaves produced–16

Leaf area–maximum area of each individual leaf, in^2—0.16, 0.47, 1.40, 2.01, 3.26, 6.04, 4.96, 9.00, 16.74, 21.70, 25.89, 41.08, 45.72, 54.40, 56.73, 35.80

- Planting date; May 25
- Planting population: dryland–50,000 plants/A, irrigated–75,000 plants/A
- Row width–30 inches
- Seeding depth–1.75 inches

Meteorological data (daily)

- Precipitation, minimum and maximum temperature, and solar radiation

Soil data

- Available water holding capacity–10.75 inches
- Initial available soil moisture–See text
- Stage 1 evaporation, (U)–0.47 in
- Slope of stage 2 evaporation–0.139 in/day

Irrigation data

- Dates and amounts

Appendix Table 1 (cont'd.)

III. INPUT DATA FOR WHEAT SIMULATION MODEL

Crop data

- Planting date–September 25
- Seeding density: dryland–45 pounds/A, irrigated–80 pounds/A

Meteorological data (daily)

- Precipitation, minimum and maximum temperature, solar radiation, and vapor pressure

Soil data

- Max available water–Field capacity minus permanent wilting point–10.75 inches
- Permanent wilting point–Theta sub V–.12
- Initial soil moisture in 59.1 in profile–Theta initial–See text
- Soil moisture evaporation phase to be used–Theta sub 5–.15
- Threshold evaporation–U–0.47 in
- Fallrt–soil moisture percent at which ET is impeded–.35
- X sub 5–initial water content by weight, in top 2 in of soil–From initial soil moisture
- FLDCP–59.1 in profile–summation of each theta max times corresponding layer depth–17.75 inches
- THEVAL–initial soil moisture on a percent by volume basis for layers 0–2.0 in, 2.0–11.8 in, 11.8–23.6 in, 23.6–35.4 in, 35.4–59.1 in–From initial soil moisture
- THEMAX–maximum theta value for each layer i.e. field capacity: 0–2.0 in–.30, 2.0–11.8 in–-.30, 11.8–23.6 in–.30, 23.6–35.4 in–.30, 35.4–59.1 in–.30
- THEMIN–minimum theta value for each layer i.e. permanent wilting point: 0–2.0 in–.12; 2.0–11.8 in–.12, 11.8–23.6 in–.12, 23.6–35.4 in–.12, 35.4–59.1 in–.12

Irrigation data

- Dates and amounts

Appendix Table 2. Gross value of crop minus total costs ($), corn

	Cropping Strategy									
Year	PP-4	PP-8	Mid-Jul	PP-4+TAS	PP-8+TAS	PP-4+TAS +BEG	PP-8+TAS +BEG	PP-4+TAS +T-B+BEG	CF	CC
1983	-164.21	-182.08	-67.76	48.63	-32.69	-95.37	-100.19	-88.31	28.74	-125.31
1982	-65.21	-124.78	-83.66	-132.57	-91.34	-94.47	-124.04	-64.31	105.54	-133.11
1981	-56.21	-80.23	-104.51	-140.07	-80.69	-58.62	-43.79	-47.06	98.94	-96.36
1980	-156.86	-135.73	-130.31	-83.97	-103.49	-64.47	-40.79	-83.96	-113.01	-117.66
1979	-97.31	-119.08	-120.26	-67.92	37.81	-63.12	-5.99	-62.06	-1.11	-53.31
1978	-114.11	51.17	-19.91	-49.32	-128.09	-77.67	-55.49	-46.76	-103.26	-116.61
1977	-85.91	-131.53	30.34	-5.82	-4.04	-37.02	-58.94	-48.56	-80.31	-108.51
1976	-142.01	-161.53	-10.76	-111.42	-102.29	-44.52	-70.49	-28.61	-77.01	-95.64
1975	-132.26	-131.38	-175.01	-89.97	-120.59	-122.82	-99.29	-77.96	-115.41	31.29
1974	-116.06	-128.38	66.04	-167.52	-183.29	-86.97	-130.34	-72.11	-106.41	-125.46
1973	-143.66	-70.48	-131.36	-139.92	-143.99	-89.52	-88.49	-43.31	-86.16	-137.61
1972	61.99	-25.03	-33.56	-123.27	-155.69	-92.97	-92.39	-57.56	-93.21	-128.01
1971	-138.41	-15.43	-8.51	-52.02	-131.69	-118.47	-76.19	-43.61	-74.91	-128.46
1970	-148.61	-114.13	59.44	-60.87	-103.04	11.43	-130.64	-118.91	-73.71	-120.96
1969	-75.86	-93.58	-104.96	-17.82	-15.14	-88.77	-92.39	-23.21	-46.26	-96.51
1968	-132.71	57.77	-164.66	-125.07	-44.69	-85.92	-35.24	-35.96	-45.81	-109.41
1967	68.59	-167.08	-169.46	-185.97	-100.49	-44.67	-58.79	-62.66	-87.36	-4.26
1966	-163.91	-122.08	-26.06	-124.17	-77.54	4.83	-73.94	-80.06	-59.61	-120.96
1965	-22.16	-161.98	-118.16	-150.57	-131.09	-81.57	-70.19	-16.61	-115.86	-118.26
1964	-158.66	-19.03	-128.06	-37.92	-60.44	-33.42	-97.94	-80.51	-82.11	82.44
1963	-100.01	-144.13	-63.86	-122.67	-28.64	-59.67	-68.24	2.59	2.19	-82.41
1962	-82.91	-141.28	-48.41	-93.72	-25.19	-48.12	-96.44	-80.51	-28.41	-118.26
1961	-131.81	-47.98	0.94	-149.97	-32.39	-47.97	-89.09	12.49	-122.91	-142.86
1960	-155.21	-158.98	-82.76	-107.97	44.41	-124.47	-151.49	-85.61	-99.36	-77.01
1959	-142.16	-83.83	-91.01	55.23	-170.54	-174.72	-97.79	-76.61	29.94	-77.16
1958	-8.21	-39.43	-89.81	-63.42	-105.44	-24.42	-47.84	-41.21	-96.51	-81.06
1957	-132.86	-146.98	-136.91	-98.37	-73.94	-80.22	-70.34	5.89	6.24	-95.16
1956	-178.46	-121.03	-142.61	-21.57	-122.24	-81.57	0.61	-118.31	-140.16	-84.66
1955	-117.41	-136.63	-84.56	-17.37	-151.34	-65.37	-92.99	-104.96	-71.46	101.49
Minimum	-178.46	-182.08	-175.01	-185.97	-183.29	-174.72	-151.49	-118.91	-140.16	-142.86
Maximum	68.59	57.77	66.04	55.23	44.41	11.43	0.61	12.49	105.54	101.49
Mean	-104.57	-99.82	-75.17	-84.05	-84.06	-71.40	-77.90	-57.53	-56.85	-85.51
Median	-131.81	-122.08	-84.56	-93.72	-100.49	-77.67	-76.19	-62.06	-77.01	-108.51
Variance	3830.51	3818.04	4214.07	3591.67	3388.13	1441.92	1178.12	1119.24	3862.53	3721.49

Appendix Table 3. Gross value of crop minus total costs ($), sorghum

	Cropping Strategy									
Year	PP-4	PP-8	Mid-Jul	PP-4+9LF	PP-8+9LF	PP-4+9LF +BT	PP-8+9LF +BT	PP-4+9LF +BT+FL	SF	SS
1983	-133.35	-73.91	0.64	-99.62	-80.31	-38.99	-39.25	-42.61	8.22	9.18
1982	-20.19	-24.71	-25.16	-101.78	-68.55	-50.75	-51.37	-59.29	12.18	-35.22
1981	-18.75	-85.19	-79.76	-33.38	-67.83	-21.59	-48.61	-21.73	3.78	-19.02
1980	-100.11	-36.59	-65.60	-9.98	-109.95	-39.23	-49.45	-20.65	-87.54	-90.06
1979	-28.35	-65.99	-112.64	-69.98	-49.47	-49.55	-30.01	-48.61	-53.46	-25.38
1978	-31.23	-35.75	-104.00	-27.38	-38.91	-38.87	-40.69	-39.73	8.70	-22.02
1977	-20.55	-44.75	-26.96	-44.30	-48.63	-43.79	-59.41	-47.41	-39.90	-90.18
1976	-126.87	-24.83	-17.48	-27.26	-46.59	-12.23	-54.85	-50.53	-2.94	14.46
1975	-92.55	-26.99	-16.28	-28.58	-72.03	-42.95	-57.97	-59.17	-25.86	-87.54
1974	-59.19	-43.43	-34.28	-38.30	-41.43	-33.59	-39.73	-47.29	-88.62	-112.86
1973	-95.07	-41.99	-27.32	-31.10	-46.59	-49.91	-59.17	-53.41	-81.66	24.90
1972	-22.23	-28.79	-8.72	-36.26	-72.51	-44.99	-49.33	-58.33	-38.94	-100.38
1971	-81.87	-39.59	-30.20	-50.90	-39.87	-31.31	-47.29	-40.69	3.66	-97.62
1970	-86.31	-74.87	-27.80	-38.30	-48.63	-56.99	-47.65	-49.45	-36.66	22.99
1969	-42.75	-44.87	-30.92	-45.38	-52.47	-50.87	-53.41	-67.57	-14.82	-57.54
1968	-29.91	-72.71	-45.68	-29.54	-37.59	-40.19	-21.85	-56.29	26.34	-101.34
1967	-26.07	-97.43	-16.40	-61.70	-40.83	-42.95	-62.17	-50.89	-1.98	-80.34
1966	-92.67	-122.39	-161.84	-50.18	-49.71	-53.75	-47.41	-39.25	-60.06	-44.70
1965	-13.47	-26.03	-77.24	-77.54	-87.87	-42.47	-65.41	-47.65	-19.62	-42.78
1964	-133.59	-128.03	-25.40	-62.18	-20.31	-47.87	-50.53	-65.41	-112.38	-61.38
1963	-101.67	-95.87	-27.92	-53.18	-94.71	-54.71	-50.89	-57.97	0.54	-56.82
1962	-12.63	-33.71	-20.24	-31.34	-41.67	-30.83	-42.61	-51.37	-64.74	-71.82
1961	-29.91	-62.27	-18.32	-36.26	-54.63	-40.91	-58.33	-50.17	-5.70	-66.42
1960	-105.51	-41.87	-49.88	-44.30	-55.71	-55.55	-50.05	-52.21	10.26	-21.90
1959	-52.11	-42.83	-40.76	-78.50	-43.71	-13.31	-56.29	-30.01	9.91	-74.34
1958	-11.31	-104.99	-75.56	-39.14	-13.59	-46.43	-63.97	-49.93	-61.38	-88.62
1957	-99.87	-7.43	-120.32	-132.74	-60.51	-42.11	-52.33	-49.33	1.74	-84.06
1956	-143.07	-61.43	-48.92	-93.74	-37.71	-34.19	-51.37	-62.17	-24.90	10.86
1955	-47.91	-43.07	-34.64	-42.14	-42.63	-41.03	-20.65	-54.73	-4.50	-67.26
Minimum	-133.59	-122.39	-120.32	-101.78	-109.95	-56.99	-65.41	-67.57	-88.62	-101.34
Maximum	-11.31	-7.43	0.64	-9.98	-13.59	-12.23	-20.65	-20.65	26.34	24.90
Mean	-60.32	-52.65	-42.57	-48.54	-52.14	-40.59	-48.98	-49.06	-22.62	-48.18
Median	-52.11	-43.43	-30.92	-44.30	-48.63	-42.47	-50.53	-50.17	-14.82	-61.38
Variance	1669.59	805.25	988.01	549.03	437.09	129.19	129.84	134.39	1157.36	1593.31

Appendix Table 4. Gross value of crop minus total costs ($), wheat

	Cropping Strategy								
Year	PP-4	PP-8	PP-4+BT	PP-8+BT	PP-4+BT +SD	PP-8+BT +SD	PP-4+JT +BT+SD	WF	WW
1983	64.61	2.86	-14.90	36.63	36.12	45.35	20.73	46.57	21.79
1982	7.70	4.96	-3.56	2.94	-2.31	31.07	40.26	19.06	0.58
1981	7.28	2.44	3.58	2.10	7.14	31.07	48.45	37.33	7.51
1980	38.57	-0.71	2.74	21.63	-20.37	31.07	43.62	60.64	2.68
1979	0.77	-9.95	4.42	1.05	1.89	-26.28	46.14	3.31	-3.20
1978	33.32	33.94	59.44	23.31	30.24	14.06	67.35	62.11	33.97
1977	76.16	64.60	24.79	-21.21	26.88	35.06	14.01	15.07	25.36
1976	11.90	2.86	48.31	25.41	5.88	-11.98	-15.39	42.79	55.39
1975	16.10	9.58	25.63	36.54	15.54	-11.98	12.75	58.54	0.16
1974	9.17	28.27	20.80	-0.21	-0.63	-11.98	49.92	13.81	2.26
1973	8.75	28.48	57.97	25.41	20.37	31.07	14.85	15.91	7.09
1972	28.49	70.69	72.25	68.88	66.15	62.57	57.48	15.91	8.77
1971	-16.66	13.36	41.80	51.66	18.48	31.07	33.33	7.30	33.13
1970	-13.93	54.10	16.39	22.05	-9.03	-11.98	10.44	2.47	-2.78
1969	10.85	2.44	-6.29	37.80	51.66	19.10	39.63	12.55	15.07
1968	-0.28	-14.57	7.15	5.25	-11.97	-26.28	26.40	-9.50	-4.67
1967	8.96	-19.19	44.11	56.91	25.20	-0.43	16.53	13.60	-4.88
1966	8.75	-20.24	31.72	40.95	53.76	17.21	-11.19	12.97	7.09
1965	46.34	41.92	23.53	59.64	18.69	-26.28	-40.80	-13.28	-16.64
1964	-7.63	2.44	24.79	-6.51	1.89	31.07	31.02	-9.08	29.14
1963	-3.64	-0.71	59.02	14.28	18.90	-11.98	5.40	-1.94	14.44
1962	-8.26	-1.76	11.56	-12.60	37.80	51.02	33.12	53.50	-7.40
1961	2.03	-13.10	27.94	19.32	43.05	20.57	45.93	56.65	17.59
1960	8.75	-3.86	7.36	-1.68	21.63	14.06	-17.49	-2.57	-0.89
1959	2.66	45.49	31.51	4.83	52.71	7.97	4.98	4.78	-14.33
1958	60.41	5.17	35.50	19.11	-1.47	-26.68	7.92	2.68	-8.03
1957	12.74	13.15	11.14	57.33	11.55	-26.68	39.63	15.07	-16.85
1956	-18.97	-24.02	-34.85	-39.69	-40.74	-11.98	-5.31	14.44	-10.97
Minimum	-18.97	-24.02	-34.85	-39.69	-40.74	-26.68	-40.80	-13.28	-16.85
Maximum	76.16	70.69	72.25	68.88	66.15	62.57	67.35	62.11	55.39
Mean	14.10	11.38	22.63	19.67	17.10	9.56	22.13	19.67	6.84
Median	8.75	2.86	24.16	20.48	18.58	14.06	23.56	14.12	2.47
Variance	563.60	623.05	583.84	658.77	574.39	628.66	628.66	510.33	287.15

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