THE ECONOMIC IMPACT OF ENERGY ON FOOD PRODUCTION

By

DWIGHT FRANCIS RYCHEL

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1970

Master of Business Administration
Florida State University
Tallahassee, Florida
1972

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Thesis Approved:

M. Palmer Terrell
Thesis Adviser

Joe H. Mize

James E. Shamblin

Charles M. Bacon

Daryll E. Ray

N. N. Durham
Dean of the Graduate College

PREFACE

This study is concerned with the evaluation of the effect energy prices and availability have on food production. For a predicted price and availability of variable inputs, the study optimally allocates these inputs to maximize the growers' profits and simulates the effect of this allocation on food prices, demand, and energy consumption. The study investigates possible future energy situations and their effect as well as investigating alternate methods and policies for food production in an energy and food conscious world.

The author wishes to express his appreciation to his major adviser, Dr. M. Palmer Terrell, for his guidance and assistance throughout this research and studies leading to this dissertation. Special appreciation is also expressed to Dr. Daryll E. Ray who patiently answered all the author's questions and without whose prior work, this research would be of much reduced significance. Appreciation is also expressed to committee members, Dr. Joe H. Mize for his guidance and support throughout the author's work, Dr. Charles M. Bacon for his advice and encouragement in multi-disciplinary systems analysis, and Dr. James E. Shamblin for his help and support.

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CHAPTER I

INTRODUCTION

Three of the most important issues facing man today are the problems concerned with the economy, energy, and food production. The problems are complex and inter-related. In considering one, one must consider the effects of the others.

Statement of the Problem

In the United States, food production, the growth, harvest, and transportation of food, consumes 4% of the total energy used. The processing, storage, and preparation of food consumes an additional 3% (25, p. 312). The dependence of agriculture on fossil energy and the competitive nature of agricultural commodities amplifies the effect energy prices and availability have on food production.

Inflation in the United States was 12.1% in the calendar year 1974. This increase was paced by a 40% increase in the cost of energy and a 25% increase in the cost of food (29). Natural gas service has been curtailed in several areas, causing partial shutdown by isolated industries, including fertilizer producers. This comes at a time when world food demand is approaching the existing production capacity and a significant number of people in poorer countries are starving.

Steinhart (25, p. 314) suggests that a reduction in America's preference for processed foods would reduce total energy in the food system. However, without more vigorous economic incentives, this is unlikely. Several realistic energy conservation measures have been proposed by Pimentel (21). The effect of these policies on energy consumption and food production can only be estimated for a given set of circumstances at one time. At present, there is no way to determine the long-range effects of time-varying conditions. It is similarly difficult to determine the effects on food production of changing energy situations due to economic or governmental action.

Research Objectives

The primary objective of this research is to evaluate and make recommendations concerning the impact of alternate energy policies and price possibilities on food production, crop prices, farm income, and energy consumption by agriculture. Specific effects will be noted on (1) raw food prices and consumer expenditures, (2) demand for crops and livestock products, (3) yield of crops, (4) energy consumed by agriculture, (5) costs of production, and (6) farm income. Energy and economic policies will be sought that will hold down the energy inputs to food production as well as the farm expenses and consumer prices while still meeting consumer demand.

This is accomplished by an optimization model designed to maximize profit through process selection, increasing with a market feed-back simulation model. These models will estimate the price, demand, and yield of crops and energy consumed by variable inputs, and the amount of the variable inputs and processes for production of wheat, soybeans, feedgrains, and cotton in the United States under varying energy conditions.

A simulation model is used because it offers the opportunity to observe the dynamic behavior of complex interactive systems. A realistic simulation provides the laboratory environment for testing hypotheses, decision rules, and alternate options. A simulation can handle the non-linearities of delays and random functions with ease and gives the user a graphic total picture of the system operating characteristics. The model is in FORTRAN IV (G level, IBM system 360) because of its universality and graphical logic.

The optimization model provides estimates of the mix and intensity of agricultural processes (planting, cultivating, fertilizing, etc.) that are most profitable to the producer for a given price of the variable inputs. The input prices are given as a function of energy consumed so that by varying the energy price the variable farm input prices vary accordingly, and produce a different profitable mix of processes. After the optimization of processes the model determines the total energy used, since the processes are given in terms of energy consumption, and total variable costs of production. When used independently, the model gives the producer the most profitable mix of alternate processes for an expected commodity price and known variable costs, subject to any constraints on resources or energy. It also shows, for that optimal mix, the energy required, by type, and the variable cost of production.

When this model interacts with POLYSIM, the farm market simulation model, the dynamic effect of the changes in energy prices and availability on market prices are simulated. In using POLYSIM to simulate the agricultural economic environment the result of estimated variable costs and the resulting yield can be seen in the supply and price of the commodity. The resulting commodity price influences the model results for the next year by changing the price per unit of the commodity the producer expects. Thus the feedback loop is established (ref. Figure 2) and the effect of energy price and availability on commodity price and production and variable costs through time is demonstrated. For the purpose of showing these effects, the decision inputs of POLYSIM are held constant at the current policy of the government, so instead of showing the market changes due to agricultural policy, the augmented model will demonstrate the effects of energy in the market. An advanced study, perhaps, may combine both of these effects. The logic of the optimization procedes as shown in Figure 1.

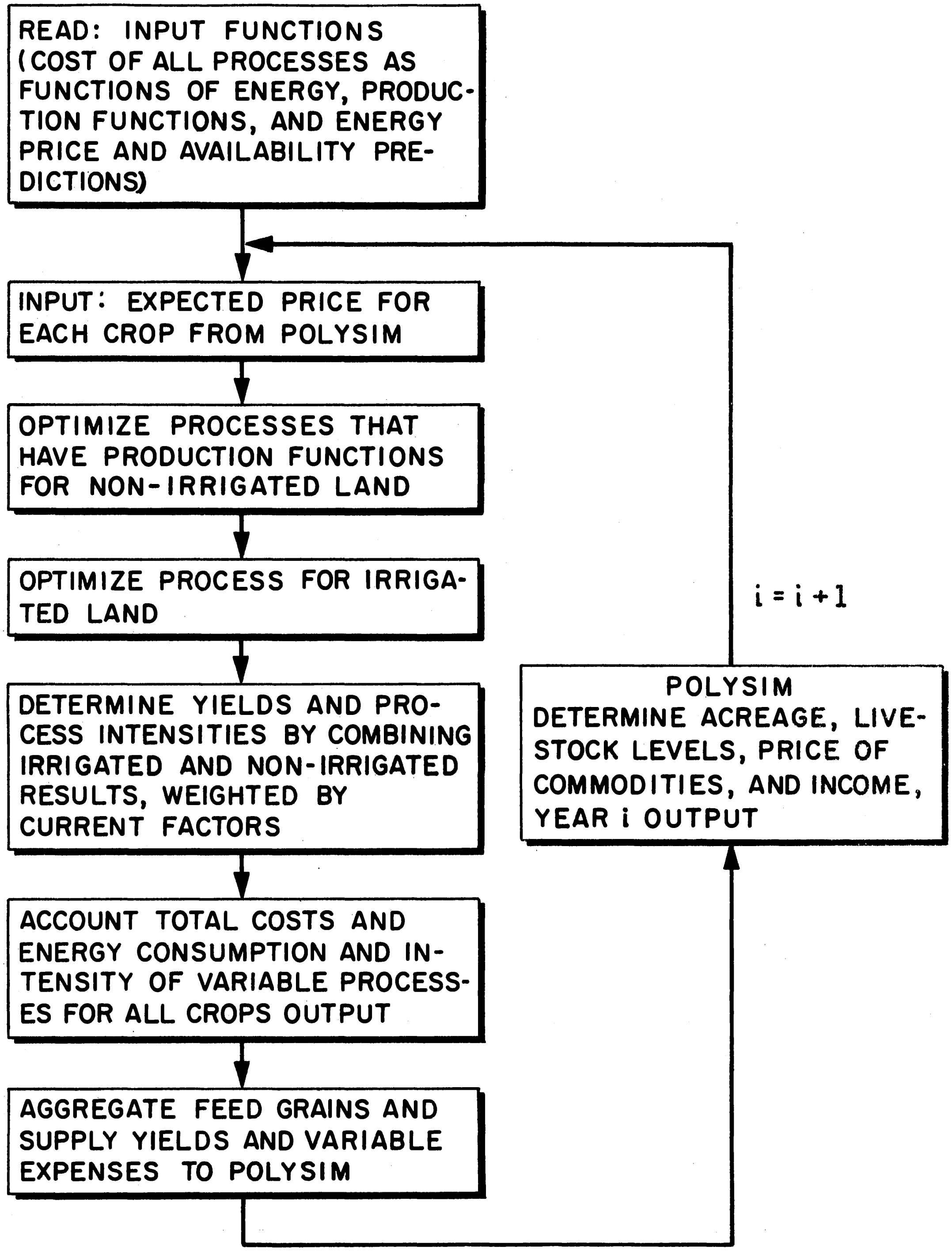

Figure 1. Optimization Logic

The model maximizes the profit of the producer. Equations 1-1 and 1-2 illustrate the profit function for corn.

$$\text{gross profit} = \begin{pmatrix}\text{commodity}\\ \text{price}\end{pmatrix} \times (\text{yield}) - \begin{pmatrix}\text{variable cost}\\ \text{of production}\end{pmatrix} \quad (1\text{-}1)$$

$$= \begin{pmatrix}\text{commodity}\\ \text{price}\end{pmatrix}\begin{pmatrix}\text{production}\\ \text{function}\end{pmatrix} - \begin{pmatrix}\text{cost of}\\ \text{processes}\end{pmatrix}\begin{pmatrix}\text{intensity}\\ \text{of processes}\end{pmatrix}$$

$$\begin{aligned}
= {} & [\text{expected price}][44.6 + 0.33\ F - 0.000\ 65\ F^2 \\
& + 4.9\ I - 0.11\ I^2 + 0.0007\ IF + 13.1\ C \\
& + 11.6\ H - 2.40\ C^2 - 2.75\ H^2 - 2.00\ CH + 48.9\ P \\
& - 29.6\ P^2] - [F(0.068 + 0.012\ G + 0.015\ N \\
& + 0.64\ KW) + I(0.33 + 0.78G + 0.07\ N + 21.33\ KW) \\
& + C(0.98 + 0.32\ G) + H(3.08 + 0.137\ G + 0.038\ N \\
& + 0.51\ KW) + P(7.32 + 0.137\ G + 0.038\ N + \\
& + 0.51\ KW)] \quad (1\text{-}2)
\end{aligned}$$

F = pounds fertilizer/acre;

I = irrigation, acre · inches;

C = cultivation, times over;

H = herbicide, lbs/acre;

P = pesticide, lbs/acre;

G = petroleum, price per gallon;

N = natural gas, price per 1000 ft^3; and

KW = price per kilowatt of electricity.

The coefficients in Equation 1-2 represent the response of yield to the variable inputs and the cost of those inputs in terms of energy. These are developed in detail in Chapter III for all crops.

Research Methodology

The research effort was accomplished in four identifiable stages. The first stage, the lengthiest, is basically organization and data reduction. It consists of (1) defining the common processes of food production, such as cultivation, seedbed preparation, planting, fertilization, and harvest; (2) determining the direct and indirect energy per acre consumed in each process; (3) calculating the variable costs of each process and the incremental cost for each energy type for each process, and (4) determining second order production functions, that is, the effect on yield of varying amounts of the process, for each process in which a variation of intensity is reasonable, as in irrigation.

The second stage is the mathematical aggregation of the data and information from the first stage. It consists of (1) stating the relationships to form an objective function of profits for a grower (profit is a function of the costs of the processes, market price, and crop yield resulting from these processes), and (2) imposing energy and resource constraints to complete the mathematical statement.

The third stage is the building and validation of the model to (1) maximize the expected profit, by selecting the optimal mix and intensity of processes that may vary in intensity subject to the stated constraints; (2) determine for each commodity, the total variable costs, yield and energy consumption; and (3) interface with POLYSIM, a market simulation model described in detail in the next chapter, to link resource use and production to commodity price utilization and farm income through time.

The final stage is the operational stage. In this stage, the effect of different energy policies and futures are simulated to determine the effect of these policies on food production, energy consumption, and prices. The results are then documented.

Organization

The documentation of the research is organized as follows:

Chapter II: Literature Review

The literature that is most directly applicable and definitive of the state of the art, relating energy and agriculture is reviewed. The market simulation model, POLYSIM, is documented in detail.

Chapter III: Agricultural Processes: Energy

This chapter discusses the direct and indirect energy that is consumed by the variable inputs to each commodity. It defines what energy is accounted and the sources. It also discusses the types and nature of aggregate production functions.

Chapter IV: Model Description

This chapter documents the details of the model. It includes applicable assumptions, the inputs to the model, the relationships of the variables, a description of the optimization algorithm, the output of the model, and the interaction with POLYSIM.

Chapter V: Alternate Policies and Futures Evaluation

The different policies, constraints, and futures simulated are described in this chapter. The results of the variations are described.

Chapter VI: Conclusions and Recommendations

This chapter contains a summary and comparison of the results of the various simulations. Predictions and recommendations are made on the results of the simulation. Recommendations are made for future research.

CHAPTER II

LITERATURE REVIEW

The literature, on which this study is built, can be divided into three groups: economic simulation, energy use in agriculture, and general agricultural statistics. There is a significant body of work in each of the three categories. There is, however, to the author's knowledge, no published work in which energy use and price are simulated with an economic model of a sector of agriculture.

There are many general texts on economic simulation. The most comprehensive and detailed work on economic feedback system is presented by J. Forrester in Industrial Dynamics (6). Forrester describes, in the text, the philosophy and methodology of simulation in interactive feedback systems. He shows how organizational structure, amplification and time delays interact to influence each other over time. He treats the interactions between flows of information, money, materials, and personnel in an industry or economy.

Many specific models of agricultural economics have been published. Ray has documented the POLYSIM model in articles and technical bulletins (22, 23). This is the model used in this research to simulate the economic effect of the prices and processes determined by the optimization model and so is described in detail.

A schematic diagram of POLYSIM is shown on the following page. The original purpose of POLYSIM was to estimate the impact of a changed agricultural policy environment, e.g., government price and income policies, on the production (acreage x yield), price, and income levels of specific commodities.

The model is constructed from previous estimates of supply and demand characteristics and USDA predictions of production, price, utilization, and income levels for major commodities from 1972 to 1980. The base predictions account for changes in relative prices and changes in supply and demand shifters such as population growth, change in national income, and consumer preferences. Given the value of these shifters, it is the interaction of supply and demand responses to prices that determines the economic response of the commodity market.

POLYSIM is a recursive feedback model utilizing the direct and crossprice elasticities for each of the commodities to determine the response of supply and demand to price changes. The percentage changes in prices from the previous year are multiplied by the appropriate direct and cross elasticities to estimate the change in commodity supply and demand. To illustrate this process, the acreage equations are:

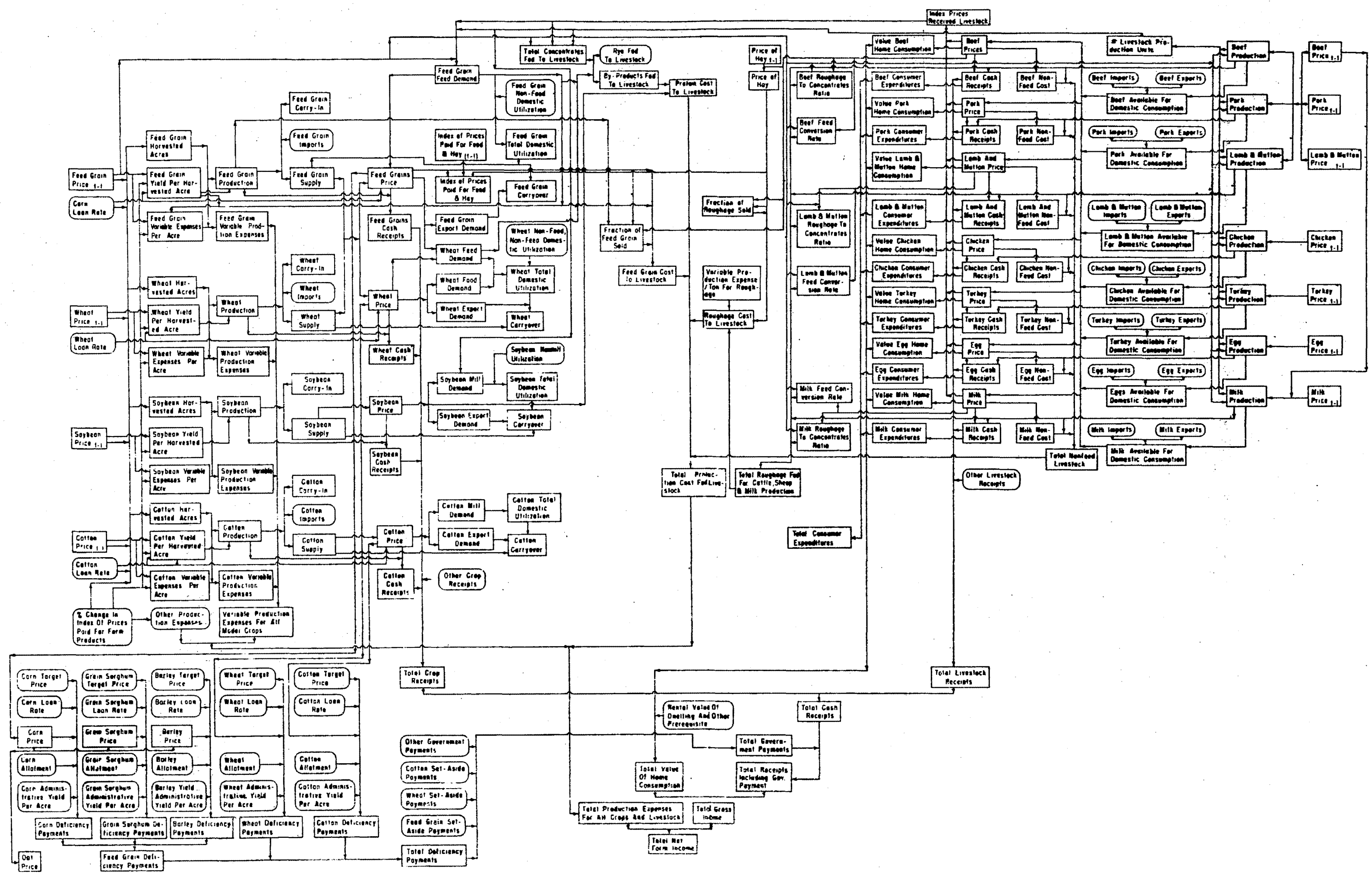

Figure 2. A Schematic Diagram of POLYSIM

$$\begin{array}{l}\text{Acreage}\\ \text{year } (i+1)\\ \text{crop } j\end{array} = \left\{\begin{array}{l}\text{Base}\\ \text{Acreage}\\ (i+1)j\end{array} \times \left[1.0 + \sum_{k=1}^{j} \frac{e_{jk}(\text{calculated-base price})_{ij}}{\text{base price}_{ij}}\right] + \left(1.0 - \begin{array}{l}\text{adjustment}\\ \text{coefficient}_j\end{array}\right)(\text{calculated-base price})_{ij}\right\} \tag{2-1}$$

where e_{jk} is the elasticity of acreage for crop j with the respect to the price of crop k.

The adjustment coefficient is to compensate for the difference in short-run and long-run price response to a sustained price change.

As currently written in POLYSIM, deviations from base yield estimates depend on estimated direct price elasticities for yield and the percentage change in previous year's price for the respective crop, and index of prices paid. This calculation will be replaced in the expanded model by the results of optimizing profits, which are functions of production functions and costs of inputs, as described in the next chapter. For a given set of prices, each process for each crop will be assigned the intensity that produces the greatest return to the producer. These intensities will determine the current year's yield for each crop. The producer's costs will be a function of energy costs. The intensity of the processes will be subject to energy and resource constraints. In addition to the yield, information will be gathered on the intensity of processes (some competing alternatives) for each crop for different prices, the energy consumed for variable inputs, and the variable costs of production. These costs will replace the current "variable production costs" in POLYSIM. This process will be described in detail in the next section.

Production is the product of the calculated yield and acreage. The crop supply identities include production, imports and carryover. Crop prices are dependent on the percentage change in calculated crop supplies and the base supply estimates. Demand, domestic and export, is dependent on the percentage change in the current and base estimates for the current year's prices of the crop and related commodities.

Livestock production levels for each of the seven classes, are based on livestock and feed grain prices from the previous year. Livestock prices are a function of the percentage change in the quantity available for consumption. Livestock production and prices in turn influence feed grain demand.

Finally, the information given as outputs, besides the information on government interaction, includes yields, production, prices, income, exports, acreages, and livestock prices and levels through time.

Several studies have been made utilizing input-output analysis. The method lends itself well to tracing flows of energy into goods and services. Most studies modify the Bureau of Census 1967 tables for the American economy to trace energy flows. Two papers that document this type research are "Use of Input-Output Analysis to Determine the Energy Cost of Goods and Services" by Herendeen (10) and "Patterns of Energy Consumption in the United States" (18), a report prepared for the Office of Science and Technology. The former emphasizes the methodology while the latter presents the data and tables.

One other study ultizing input-output analysis and concentrating on food production is "Energy Use for Food in the United States," by E. Hirst (12). It gives detailed information on energy inputs at each stage of food production from growing to processing to preparation for consumption. The obvious limitation on input-output analysis is its static nature. It is an excellent means of determining flows of energy or money to end products, but cannot show the effects of time varying changes.

Two related articles have appeared in Science documenting the energy currently being used in food production and the trends of increasing energy consumption. The articles, one by Steinhart and Steinhart (25), the other by Pimentel (21), describe the implications of increasing energy use, look to the future, and suggest methods to reduce energy use.

A more specialized paper by Emmons (5) follows the general methods of the papers above to determine in detail the direct and indirect energy use on a typical farm producing peanuts in Oklahoma. This paper shows in detail, for each farming process, the direct energy consumed and the energy inherent in the variable inputs, such as irrigation and fertilizer. Many of the sources and methodology of this paper were used by this author for data collection and reduction to determine the energy used in the production of the seven crops considered in this research.

The last category of literature, general agriculture information, includes literature on farm and market processes and general statistics. Many texts are available that describe the pricing environment of agriculture. Similarly, several texts are available that discuss yield response in general. One of these, Grain Yields and the American Food Supply by Johnston and Gustafson, was particularly helpful (14). The authors discuss qualitatively and quantitatively the factors that affect yields of specific grains and the magnitude of that effect. They discuss effects of geography, changes in weather, and the influence of price on grain yield. Also discussed are man's influence on yield: fertilizer, improved seed, irrigation, summer fallow, and weed control. They make predictions on further increases in yield from current observations and past performances.

There is a tremendous wealth of published research on yield responses to variable inputs of fertilizer, irrigation, cultivation, herbicide, and pesticide. The description of this type document is deferred until the next chapter, as is the specific information as to how the production functions in this study were derived.

Finally, the Bureau of Census and the United States Department of Agriculture Economic Research Service periodically compile and publish information and statistics on inputs and outputs of agriculture. Much of the base data was from the Bureau of Census's 1973 Agricultural Annual. The "World Fertilizer Situation, 1975" provided much of the information on the quantity and composition of fertilizer in the United States. Other statistical sources too numerous to mention will be documented in the succeeding chapters where the information is applicable.

CHAPTER III

AGRICULTURAL PROCESSES: ENERGY INPUTS AND YIELD EFFECTS

Energy Inputs

As our society attains higher degrees of technology, its products become more energy-intensive. In food production, energy is used in many forms. It is used directly as fuel for tractors, equipment, and transportation. Also, it is used for irrigation and drying in various forms. These direct uses only constitute a portion of the energy used in agriculture, however. In addition to the direct energy used on the farm, the products used on the farm have an indirect energy content. This includes fertilizer, seeds, chemicals, and any other variable input to food production. Every raw material, every finished good has inherent energy content. This is the energy required to extract, process, transport, and manufacture articles. As demand and yields increase, agriculture consumes proportionally more indirect energy.

This research investigates the direct and indirect energy used in the variable inputs to food production, those inputs that increase proportionally with each acre under production.

Different products generally require different processes. The equipment and processes used for the same crop in one part of the country may be quite different in another part. The equipment required to initially break the soil is considerably different for clay than for sandy loam. Some soils may require harrowing or other cultivation. Different climates have different pests, so weed and insect control will vary. For a specific area, the processes may be more exactly tied to a specific piece of equipment or production technique. This is impossible for an aggregate study. For this reason, the processes defined for this study are quite general.

The processes, utilizing the variable inputs to the production of the commodities are (1) pre-planting tillage, which includes all processes between harvest one season and planting the next, plowing, discing, harrowing, all soil preparations; (2) planting; (3) fertilizer application, including selfpropelled sprayers, dry fertilizer applicators in tandem with planters, and sprayers; (4) herbicide application, custom and sprayed; (5) cultivation, including all tillage after planting and before harvest, row tillage on row crops and cultivation of fallowed acreage of small grains; (6) application of pesticide, both ground and aerial applications; (7) irrigation; (8) harvesting, both custom and self harvest; (9) drying those applicable crops; and (10) transportation to the storage area, including year-round use of pickup and truck.

The direct energy included in the study is the fuel used by tractors, equipment, and trucks, and the energy used in irrigation and drying. The indirect energy included is the energy required to produce seeds, herbicide, pesticide, and fertilizer.

The energy associated with fixed inputs, while not a part of this study, should be pointed out to the reader. Farm machinery and repairs to machinery are a considerable use of energy. It is beyond the scope of this research, however, to determine what the effects of energy prices would be on fixed inputs. Similarly the electricity for home use and the energy used in the maintenance and construction of outlying structures is not included.

The fuel used for each process and each crop by tractors, trucks, and equipment was calculated from selected United States Department of Agriculture Economic Research Service regional enterprise budgets. They were selected in the areas where each crop is dominant, weighted to represent the national average figures. The budgets give average times over for each process and the fuel consumed for each particular equipment and process.

The following are the budget document numbers that were used in this research:

wheat	4/38/2/0 4/20/0/0 4/20/1/0 4/38/1/0	corn	4/20/4/0 4/38/3/0 4/20/3/0 4/31/5/0
oats	9/8/0/0 4/46/4/0	barley	9/8/0/0 4/38/2/0

sorghum	4/20/0/0	soybeans	4/31/0/0
	4/20/3/0		6/13/5/0
	4/20/4/0		
cotton	6/13/5/0		
	6/13/4/0		

Each budget represents from 1 million to 4 million acres, so six to seven percent of the crop production is used as the sample. The information from each budget is weighted by the fraction of the sample acreage it represents. The specific items weighted were: (1) times over for each specific process, (2) fuel required for each process per time over, and (3) variable costs associated with each process, less fuel.

Table I shows the average times over, fuel used, and costs as a function of fuel for each crop for the preplanting tillage. Each column reflects average data from selected Regional Enterprise Budgets, weighted by crop acreage.

The costs for preplanting tillage, beside fuel, include tractor and equipment repair, labor, interest, and insurance. The prices are in 1972 dollars and are adjusted by Department of Agriculture predictions of costs from 1970-1980. All of the baseline data in this study are 1972 data, the most recent year for which full statistics are available.

Table II shows the variable cost for planting each crop as a function of fuel. These costs are from the Regional Enterprise Budgets, weighted as previously described. The costs, less fuel include tractor and equipment repair, labor, insurance, seed, and interest. Seed prices are a function

TABLE I

VARIABLE COSTS FOR PREPLANTING TILLAGE

Crop	Acreage Times Over	Fuel per Times Over/ Acre in Gallons	Variable Cost per times over/acre less fuel
Wheat	2.1	0.42	$1.60
Soybeans	3.0	0.44	0.92
Cotton	4.0	1.12	1.26
Corn	2.8	0.43	0.98
Sorghum	3.2	0.42	1.11
Oats	1.78	0.54	1.03
Barley	1.68	0.58	1.29

Source: Derived from E.R.S. Regional Enterprise Budgets.

TABLE II

VARIABLE COSTS FOR PLANTING

Crop	Fuel/Acre Gallons	Seed/ Acre	Variable Cost per Acre Less Fuel & Seed	Ratio: Seed/ Grain	Indirect Seed Energy per Acre		
					Petr. Gal.	Nat. Gas $10^3 ft^3$	Elect. KWH
Wheat	0.54	1.2 bu	$1.60	1.57	0.35	0.029	1.1
Soybeans	0.70	1.0 bu	$0.92	2.0	0.28	0.004	1.13
Cotton	1.01	22 lb	$1.39	0.8	1.32	0.098	6.16
Corn	0.31	.24 bu	$0.98	10.0	0.361	0.08	3.52
Sorghum	0.36	0.1 bu	$1.11	7.0	0.21	0.032	1.62
Oats	0.74	2.4 bu	$1.23	1.7	0.46	0.017	2.16
Barley	0.63	1.6 bu	$1.29	1.6	0.42	0.012	1.2

Source: Fuel, seed rates, and variable costs derived from ERS Enterprise Budgets. Seed energy is fraction of total energy used, according to yield.

of the expected market price (see Table II). Tractor and equipment repair and machinery labor are allocated on a times over basis for preplanting tillage, cultivating, planting, and fertilizing. The energy content of the seeds was calculated by adding the energy used per acre, dividing by the yield and multiplying times the seed rate/acre. Fertilizing is generally done near planting time, so all fertilizing equipment costs are charged to planting. The cost of fertilizing is just the cost of the fertilizer. These costs are shown in Table III as a function of energy. The energy for fertilizer for each crop is a sum of the portional energy for the specific amount of nitrogen, phosphorous, and potassium used in the aggregate in 1972 (35, 29). The total energy required for a pound of each fertilizer component is from Emmons (5, 18). The energy mix is from "The World Fertilizer Situation" (36, 45). The price, less energy is again from selected Enterprise Budgets. The petroleum classification includes diesel, gasoline, and liquid petroleum.

Cultivation costs are shown in Table IV. Cultivation for small grains includes the cultivation of fallowed land, weighted by the 53 percent of small grain cropland fallowed in 1972 (26). All ground preparation costs are counted in preplant tillage (Table I). The cultivation data is derived in the same manner, from the same source as the preplant tillage.

TABLE III

FERTILIZER COSTS

Crop	Percent N	Percent P	Percent K	Energy/Pound Petroleum Gallons	Energy/Pound Nat. Gas $10^3 Ft^3$	Energy/Pound Elect. KWH	Cost Less Energy $/pound
Wheat	56	32	12	0.013	0.017	0.60	0.075
Soybeans	10	39	51	0.010	0.003	0.88	0.094
Cotton	51	27	22	0.012	0.016	0.63	0.068
Corn	48	26	26	0.012	0.015	0.64	0.068
Sorghum	68	14	18	0.012	0.020	0.51	0.048
Oats	28	29	43	0.008	0.008	0.76	0.078
Barley	49	46	5	0.013	0.015	0.68	0.097

Source: Mixture from ref. 36.
Energy/pound from ref. 5.
Costs from Enterprise Budgets.

TABLE IV

VARIABLE COSTS OF CULTIVATION

Crop	Average Times Over	Fuel per Times Over/Acre in Gallons	Variable Cost per Times Over/Acre, Less Fuel
Wheat	1.68	0.42	$1.60
Soybeans	3.5	0.42	$0.92
Cotton	3.0	0.84	$1.26
Corn	2.0	0.32	$0.98
Sorghum	2.0	0.32	$1.11
Oats	1.95	0.48	$1.03
Barley	1.99	0.48	$1.29

Source: Derived from E.R.S. Regional Enterprise Budgets.

The cost of herbicide application includes the cost of spraying: labor, equipment, and fuel plus the cost of the herbicide, which can also be expressed as a function of the cost of the energy required to produce it. The cost per pound is an average estimate for all herbicides as the production function in the next section is average. It is assumed the effectiveness and energy content per dollar of herbicide remain constant over the spectrum of available herbicides.

The variable cost of spraying is from the Enterprise Budgets, and is the same regardless of crop, reflecting an average from all application methods. The energy content for herbicide and pesticide is from Emmons (5, 18). The mix is from energy consumed in the production of agricultural chemicals as documented in the 1967 Census of Manufacturers (27, 28F-18). These costs and energy uses are shown in Table V for all crops.

The variable costs of irrigation are for labor, equipment repair and fuel for the pumps. The 1972 mix of energy used in irrigation was 22% petroleum, 16% natural gas, and 62% electricity (33). With these percentages the average energy used for one acre-inch of irrigation is 0.78 gallons of petroleum, 0.07×10^3 cubic feet of natural gas, and 21.33 kilowatt-hours. Table VI shows the non-energy variable costs of irrigation (5, 20).

The only crops to use a significant amount of pesticide are cotton, corn, and soybeans (28). The costs of application

TABLE V

VARIABLE COST OF HERBICIDE APPLICATION

Energy per pound of herbicide			cost/pound
Petrol. Gal[1]	Nat. Gas 10^3 Ft^3	Elec. KWH	Less Energy
0.132	0.038	0.51	$3.08

[1]Includes fuel for applicating equipment and indirect for herbicide manufacture.

Source: Energy content from ref. 5. Cost, less energy, from Regional Enterprise Budgets.

TABLE VI

VARIABLE COSTS FOR IRRIGATION

Crop	Non-fuel Costs Dollars Per Acre-Inch Irrigation
Wheat	0.33
Soybeans	0.33
Cotton	0.42
Corn	0.33
Sorghum	0.32
Oats	0.28
Barley	0.28

Source: Derived from Regional Enterprise Budgets.

and energy content are the same as herbicide for pesticide application. Cotton requires frequent spraying with aircraft and self propelled sprayers, typically 10 applications of 2/3 pounds per acre (31). The energy content and application cost is the same as that derived for herbicide, but the pesticide is more expensive, $7.32 per pound, applied, less energy costs (Table VII).

The costs of harvests from the Enterprise budgets, beside fuel, include custom combining, equipment repair, labor, and interest. It does not include transportation or drying. Corn and sorghum are the only crops requiring a significant amount of drying. These costs are shown in Table VIII (8).

The final process, transportation, includes transportation after harvest and truck and pickup use during the growing season. Besides fuel, it includes the cost of repairs, labor, insurance, and interest. The data is from the Enterprise Budgets (Table IX).

Variable Inputs and Yield

In the last 40 years, crop yields have increased significantly, nearly doubling for most crops. This increase is due to improved seeds, an increase of mechanization, irrigation, and chemical inputs of fertilizer, herbicides, and pesticides, and, for some crops, an increase of fallowed land. Energy input to the U.S. food system has increased four-fold in the same period, according to Steinhart (25).

TABLE VII

VARIABLE COSTS FOR HARVEST

Crop	Fuel Gallons/ Acre	Harvest Cost $/Acre, less fuel
Wheat	1.97	3.00
Soybeans	2.52	3.45
Cotton	8.00	52.50
Corn	2.15	5.67
Sorghum	2.15	3.22
Oats	2.40	3.40
Barley	2.94	3.17

Source: Derived from Regional Enterprise Budgets.

TABLE VIII

DRYING COSTS

	Energy/Acre		
Crop	Petroleum Gal	Nat. Gas 10^3Ft^3	Elec. KWH
Corn	3.9	0.70	11.8
Sorghum	1.9	0.33	5.9

Source: Ref. 8.

TABLE IX

VARIABLE TRANSPORTATION COSTS

Crop	Fuel Use Per Acre Gallons	Costs Less Fuel $/Acre
Wheat	5.43	2.31
Soybeans	6.05	1.05
Cotton	7.60	2.72
Corn	7.02	1.57
Sorghum	4.37	1.40
Oats	3.68	0.81
Barley	5.15	1.88

Source: Derived from Regional Enterprise Budgets.

Johnson and Gustafson (14) estimate that future increases in grain yields may be made not only with increases in fertilizer rates, but with improved seeds, cultivation practices, herbicides, and insecticides. They further state that further increases in summer fallow, unless associated with an expansion of the sown area, are not likely to have much influence on total grain output. Also, expansion of irrigation is likely to have only a minor effect on yields unless grain prices rise significantly, bringing increased irrigation in humid areas, which would have a measurable impact on yields.

Agricultural production functions mathematically define yield as a function of agricultural inputs. Production functions are derived as a result of controlled experiments and fitting the results to an assumed model. The difficulties of deriving aggregate production functions, however, are considerable and must be recognized.

Headley and Lewis (9) have pointed out several problems in the formation of any aggregate production function from experimental data. First, experimental observations may relate to a higher standard of production than found in the aggregate. That is, the timing or application method may be more effective. Second, there is difficulty in obtaining readings throughout the normal operating range. Too often the research determines the effect with or without treatment, or just a few discrete points. Third, extreme care in experimental design must be made to insure results are not obscured by uncontrolled variables. Fourth, the time relationship of most processes must be considered as well as the effect of bordering areas. Finally, soil and climate at the experimental sites may not represent the aggregate.

There are other problems unique to weed and insect control. The crop level of infestation may be considerably heavier or lighter than normal, or the results unique only to a particular pest. Also, there may be improvements in the quality, as well as the quantity that would result in higher profits.

These problems are minimized by careful experimental design: control of inputs, duplication of normal standards, conducting the experiment over several seasons, in large areas and several regions, and obtaining as many data points as possible. As much as possible, the production functions obtained and derived in this paper were developed from research conducted under the above conditions.

Ibach and Adams (13) conducted exhaustive research in fertilizer production functions for 76 regions of the United States. The author has selected those regions for each crop that represents the most total acreage and weighted them to obtain an aggregate function. These are shown in Table X. The results in Table X were obtained by averaging the data from the most significant areas for each crop and shifting the curve upward, if required, to reflect 1972 technology. The shift was accomplished by adjusting the linear term so that the 1972 aggregate yield matched the 1972 fertilizer rate.

TABLE X

FERTILIZER PRODUCTION FUNCTIONS

Crop	Yield
Wheat	$21.0 + 0.32\ F - 0.0022\ F^2$
Soybeans	$18.9 - 0.50\ F - 0.0069\ F^2$
Cotton*	$180.0 - 4.7\ F - 0.0153\ F^2$
Corn	$44.6 + 0.33\ F - 0.00065\ F^2$
Sorghum	$27.1\ \_\ 0.55\ F - 0.00214\ F^2$
Oats	$40.2 + 0.43\ F - 0.00341\ F^2$
Barley	$34.5 + 0.24\ F - 0.00250\ F^2$

*Yield is pounds of lint/acre, all others are bushels/acre.

F = pounds fertilizer at 1972 ratios of nitrogen, phosphorus, and potassium.

Source: Ref. 13.

Irrigation also has a significant effect on yields in dry areas. Heady, et al. (11), have compiled production functions for corn, wheat, and cotton. The work accounts for the cross-product effect of fertilizer and irrigation used simultaneously. These production functions and information presented in the Irrigation Handbook and

Directory were used to determine the production functions for the lesser irrigated crops of oats, barley, sorghum, and soybeans by fitting the second order curve to the expected maximum increase in the shape of similar grains (14). Assuming an average of 10 inches of rainfall over the growing season in irrigated areas, the production functions for irrigation are shown in Table XI.

TABLE XI

IRRIGATION PRODUCTION FUNCTIONS

Crop	Change in Yield Base
Wheat	0.75 I - 0.010 I^2 + 0.0020 (I) (F)
Soybeans	0.74 I - 0.0113 I^2 + 0.00028 (I) (F)
Cotton*	- 148 + 16.49 I - 0.302 I^2 + 0.017 (I) (F)
Corn	- 31.7 + 4.9 I - 0.11 I^2 + 0.0007 (I) (F)
Sorghum	- 24.0 + 3.3 I - 0.070 I^2 + 0.0012 (I) (F)
Oats	- 11.0 + 2.1 I - 0.014 I^2 + 0.0016 (I) (F)
Barley	- 3.5 _ 1.1 I - 0.0098 I^2 + 0.0024 (I) (F)

I = Acre-inches of irrigation.

F = pounds of fertilizer per acre at 1972 ration of N-P-K.

*Cotton yield is pounds of lint/acre, all others are bushels/acre.

Source: Ref. 11.

Weed control, or lack of, has a dramatic effect on yield. Assuming the grower starts with clean seed, weed control is accomplished by mechanical means or with herbicide, or some combination of both. Row crops, corn, sorghum, and cotton, may be cultivated during the growing season. Small grain cultivation is confined to a normal soil preparation and cultivation of fallowed land.

There are several periodicals and societies that publish the results of weed control research. There is available data for all methods of weed control and all crops. Equation (3-1) is derived by regression from research data by Burnside and Wicks (3), for sorghum weed control.

Sorghum:

$$\Delta Y = -15.15 + 6.5\ C + 5.8\ H - 1.2.\ C^2 - 1.51\ H^2 - 1.01\ CH \qquad (3\text{-}1)$$

C = Cultivation, times over;

H = Herbicide, pounds/acre (one application); and

ΔY = change in base yield.

Equation (3-2) is similarly derived from data submitted by Meggitt (16) on weed control in corn.

Corn:

$$\Delta Y = -19.01 + 13.1\ C + 11.6\ H - 2.40\ C^2 - 2.75\ H^2 - 2.00\ CH \qquad (3\text{-}2)$$

Equation (3-3) represents the effectiveness of cultivation and herbicide in soybean yield, from research by Burnside and Colville. Equation (3-4) is derived from research in cotton weed control by Dowler and Hauser (2, 4).

Soybeans:

$$\Delta Y = -8.12 + 3.95\ C + 2.90\ H - 0.610\ C^2 - 0.75\ H^2 - 0.65\ CH \qquad (3\text{-}3)$$

Cotton:

$$\Delta Y = -509.5 + 260.1\ C + 115.4\ H - 29.65\ C^2 - 28.7\ H^2 - 9.2\ CH \qquad (3\text{-}4)$$

The soil preparation for grain production is, within a small variance, fixed, so the weed control production functions are a function only of herbicide. Equations (3-5 through 3-7) are for barley, wheat, and oats, respectively (20, 9).

Barley: $\Delta Y = -2.2 + 12.1\ H - 9.8\ H^2$ (3-5)

Wheat: $\Delta Y = -1.18 + 5.86\ H - 4.75\ H^2$ (3-6)

Oats: $\Delta Y = -1.2 + 10.5\ H - 7.2\ H^2$ (3-7)

Pesticide, as mentioned in the previous section, is only used, to any extent, on cotton, corn, and soybeans. The production functions for these crops are Equations (3-8 through 3-10), respectively (9).

Cotton: $\Delta Y = -152 + 34.8\ P - 2.51\ P^2$ (3-8)

P = pounds per acre of pesticide

Corn: $\Delta Y = -16.0\ \_\ 48.9\ P - 29.6\ P^2$ (3-9)

P = pounds per acre of pesticide

Soybeans: $\Delta Y = -3.7 + 51.0\ P - 140.0\ P^2$ (3-10)

P = pounds per acre of pesticide

CHAPTER IV

MODEL DESCRIPTION

As described in Chapter I, the purpose of the model is to act as a vehicle to make a realistic simulation of the agricultural market. Specifically it will simulate the reaction to different energy prices and availabilities and alternate farming processes, over a period of several years. The reaction is observed in crop yields, prices, and production as well as livestock products' (beef, pork, lamb, poultry, eggs, milk) prices and production. In addition, the amount and type of energy and variable costs used in each situation may be compared.

The complete model is a merger of two models: the first, POLYSIM, is an economic model by Ray described briefly in Chapter II; the other model is an optimization and accounting model, created for this study. This model is constructed to interface with POLYSIM. Its logic and the interface will be described in detail in this chapter.

Model Logic

In Chapter I and Chapter II, the basic flow of each of the two models was described briefly, independent of each other. In the general discussion that follows, the logic of the complete model will be outlined, with detailed information about the process optimization and energy calculation model following.

The model flow is diagrammed in Figure 3. The first five blocks are for the initialization of the simulation run(s). The economic portion of the model is based on the U.S. Department of Agriculture Commodity Economic Division predictions of production, yields, and prices for commodity and livestock products and estimates of elasticity from independent research. These predictions, the baseline data, are stored on disc to reduce input requirements. The first step of the program is to read this data off disc storage. Then, user supplied information is read in. This includes the project name, number of years to be simulated, the beginning year, market options (free or support) and optional information on target prices, loan rates, production, and yields. This information is used to initialize all files. The simulator uses data from the year being simulated first and the two previous years to initialize conditions. Two parallel files of information are stored: baseline and simulated values. This parallel storage is because of the nature of most calculations multiplies the percentage difference between baseline and simulated values by the appropriate elasticity coefficient. In addition, all exogenous information is filed. The user then has the option to supply his own elasticities, the long term and short term

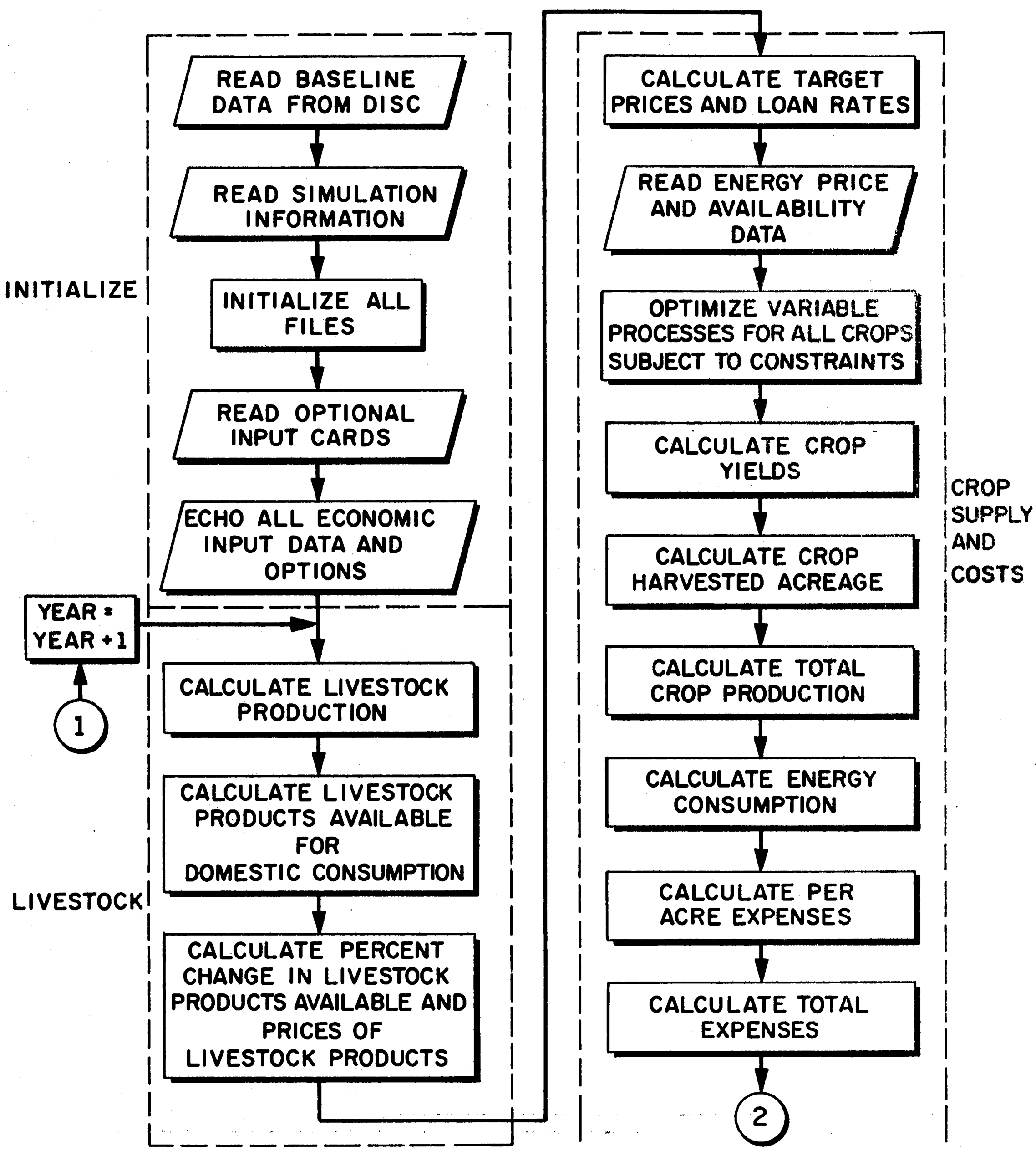

Figure 3. Model Flow Chart

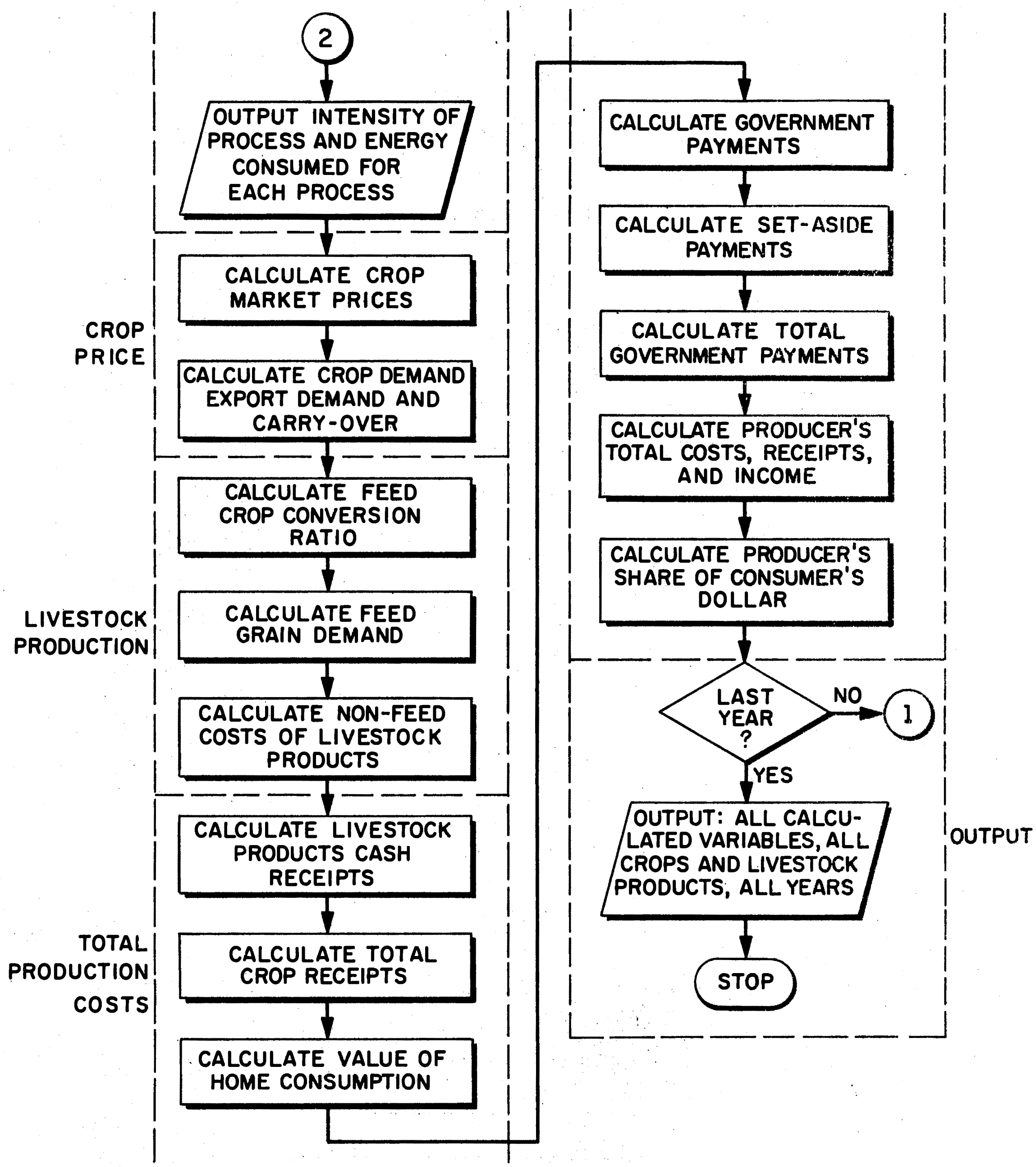

Figure 3. (Continued)

price flexibility. The final step in the initialization is to echo all the user supplied input data and options.

The next series of three blocks begins the first year simulation and deals with the livestock products supply and the receipts of the producer. The first calculation is livestock production. All livestock product calculations are made for beef and veal, pork, lamb, chicken, turkey, eggs, and milk. The production calculations are based on the product's previous year's price, the percent difference between baseline and simulated feed grain price and the differences in prices of competing products times the appropriate direct and cross elasticities. With this production information, and the import and export demand, the livestock products available for domestic consumption are computed. The last section of this series calculates the percentage change in livestock product availability, and with this information and the known price flexibility, the current year's price for each of the livestock products is determined.

The next series of ten blocks determines crop supplies and production costs for each crop. It is in this section that the optimization and energy model interfaces with POLYSIM. The first crop calculations determine the target prices and government loan rates for feed grains, wheat, soybeans, and cotton. Where these prices exceed the previous year's calculated market price they are used as the expected price. Next, user supplied information is supplied for each crop, each year, on energy prices (petroleum, natural gas, and electricity) and availability. At this point, the feed grain category is broken down to corn, sorghum, oats, and barley.

The energy and crop price information is then substituted into the production functions described in Chapter III and the level of each of the variable processes are sought that maximizes the income of the producer, possibly subject to constraints on the amount of each type of energy used and the amount of each specific process. By variable processes, it is meant those processes that may be varied in intensity to vary the yield. These include fertilization, herbicide application and irrigation for all crops, cultivation for the row crops of corn, cotton, soybeans, and sorghum, and pesticides for cotton, corn, and soybeans. The optimization process is described in a later section of this chapter.

Once the optimal mix of processes is determined, the production functions define the aggregate yield for each crop. The harvested acreage for each crop is determined, as described in Chapter II, from the baseline acreage, the percent deviation in last year's crop market prices from the baseline projections times the appropriate direct and cross elasticities, and the adjustment coefficient for long and short term changes. The total production for each crop is then simply the product of the yield and the number of acres harvested.

The energy consumed per acre for each crop is calculated from equations derived in Chapter III. The energy and cost calculations will be detailed in a later section of this chapter. The total energy use, by type, associated with variable inputs is obtained by multiplying the per acre amounts times the production of each crop and summing over all crops. Similarly, the per acre expenses for each crop are calculated from the relationships derived in Chapter III. These expenses cover those processes that are optimized above as well as those that are fixed in intensity, such as planting and harvesting. They are a function also of the price of last year's crop because of the purchase of seed for this year's crop. The total expenses then are the per acre expenses times the acreage harvested.

At each iteration, the detailed results of the optimization and energy section is printed for each crop. This includes the intensity of the variable processes, the per acre energy used in the production of each crop, by type of energy, the yield, and the per acre expenses.

The next two blocks comprise the crop price and demand section. With the production information from the previous section, and the predicted import and export demand, and appropriate direct and cross elasticities, the current price for each crop is calculated. This is done in the same manner as the livestock prices in the second section. The current market price and the baseline price is used to calculate crop demand and export demand. The carry-over (stocks on hand) is then adjusted as required by production and demand differences.

The next series of three blocks covers livestock production costs. The initial calculation is the feed conversion ratio. This is the ratio of pounds of feed to pounds of product (live weight for the livestock themselves). It is a function of the previous year's price for the product and for feed and the baseline ratio. Next, feed grain demand is computed from the livestock production levels, the feed conversion ratios, and the fraction of feed grains used for each product. Finally, the non-feed costs of livestock products are calculated from baseline data at the assumed inflation rate.

The final eight blocks of the iterated group are concerned with the producers' costs, receipts, and income. The first step calculates the livestock products' cash receipts, based on the quantities produced and prices. Similarly, the total cash receipts for the crop production is calculated. The value of home consumption is calculated as a function of the baseline value and changes in commodity prices.

Government support payments are calculated as a function of the assumed target price, loan rate, and market price. Government set-aside payments are calculated according to the user-supplied specifications and current production. These are summed to determine total government payments.

Complete calculations are made of the producer's costs, receipts, and income. These include total receipts, total gross income, crop expense, protein, feed, roughage, and nonfeed costs to livestock, total variable costs, total production costs, and total net income.

At the end of the last simulated year, all calculated values, those included in production, pricing, receipts, and income, are available as output at the option of the user. A sample output is included with the source listing in the Appendix.

Assumptions

Several assumptions are inherent in the simulation. Some are restrictions imposed by the data sources, others from the model performance. The time span chosen for the simulation is five years. This is a convenient planning period and is of a reasonable duration so that those assumptions of negligible environment changes are justified.

Obviously, the model has no provisions for catastrophic events, or even sustained abnormal events. These are infrequent random events and beyond the scope of this research. It is assumed that the production functions and the cost and energy functions, derived from weighted regional data adequately describe the aggregate production as described in Chapter III.

Several factors are assumed to remain fixed for the duration of the simulation. First, there is no shift of crops within the feed grain category. Such a change could significantly change the yield and total production while the acreage remained constant. However, there is no history of any past dramatic shifts or evidence of any future shifts among the feed grains. Second, the energy and other cost contributing inputs to the "fixed" processes of planting, harvesting, cultivation of fallowed land, pre-plant tillage, and transportation remain constant. That is, there is no significant conservation or change in the method of performing these processes. Third, the energy and cost contributing inputs to the variable processes are constant for any given intensity of the process. Fourth, the supply and demand direct and cross price elasticities remain constant. It is recognized that response to short and long term price changes produce different results and these are accommodated in the model with an adjustment factor. Fifth, the ratio of Nitrogen, Phosphorous, and Potassium used as fertilizer for each crop will remain constant at the 1972 level. This means, if because of energy shortages, one is available only in a restricted amount, the producer does not attempt to compensate by using proportionally more of the other two. Sixth, the average effectiveness, price, and energy required to produce agricultural chemicals (herbicides, pesticides) will remain constant. It is recognized that there is a wide variety in prices and effectivity for specific pests and in specific regions. The figures used in this study are assumed to be the aggregate average. Seventh, seed technology (the development of hybrids of increased yield or hardiness) will have no short-term effects. Long-term effects are recognized and are built in to the baseline figures generated by the U.S. Department of Agriculture. Eighth, change in the portion of the land used in irrigation for each crop is linear with respect to the amount of irrigation per acre that is economically desirable. Fraction of land irrigated is initially set to equal 1973 figures, with 1973 irrigation intensities.

It is further assumed that, unless otherwise constrained, the crop producer will use the amount of inputs that will maximize his net profits. Where this is not realistic because of resource availability, the process will be constrained at current or predicted levels.

Finally, it is assumed that there will be no significant changes in the government subsidy and set-aside programs during the simulation. While it is possible to simulate any such changes, it is desired that the results not be clouded by making simultaneous changes in energy price and availability and the government environment.

Optimization Algorithm

The basic purpose of this research, as previously stated, is to determine yield, costs, and energy usage at various prices and availabilities. The approach has been to sum the costs and energy used in the processes of crop production and to use the intensity of these processes with production functions to determine yield. This operation is straightforward for those processes that are fixed, that is, those that must be done once, and in the same manner for each year. These include pre-planting tillage of the soil, planting, harvesting, tillage of fallowed land for small grains, drying of corn and sorghum, and transportation of all crops. Other processes, however, may be used to varying degree, and the degree to which they are done affect the energy, costs, and yield per acre of the crop.

The yield effect can be linked to price through yield elasticity coefficients. These would indirectly reflect the reduction of the variable inputs of fertilizer, herbicide, pesticide, and irrigation due to reduced market prices of the crops, but do not give a direct measurement of the reduction of the processes. Without a direct estimation of the intensity of the variable processes, it is difficult to determine the per acre expenses and energy consumption.

Logically, one would expect the grower to use the amount of the variable inputs that would maximize his income subject to the availability of that input. It is this assumption that determines the manner of the model of the variable inputs to crop production. Income in excess of variable cost is defined as gross receipts minus per acre costs. The simplified objective then is to:

Maximize: (4-1)

$$(\text{yield})\begin{pmatrix}\text{price}\\ \text{of crop}\end{pmatrix} - \sum_{\substack{\text{all}\\ \text{processes}}} \begin{pmatrix}\text{amount of}\\ \text{process}\end{pmatrix} \times \begin{pmatrix}\text{cost per}\\ \text{unit process}\end{pmatrix}$$

The income is maximized by the optimal selection of process intensity for the specific crop price and specific cost per unit process. In this model, the expected crop price for the current year is the price determined in the previous simulation period. This is the price upon which the producer will base his decision. The cost per unit process is represented by a constant plus the cost of the energy required for that unit. The constant, which may be adjusted for alternate inflation rates, includes labor, equipment repair, interest, insurance, and the non-energy cost components of other inputs. The yield is expressed in terms of those processes that may be varied in intensity. These are the production functions discussed in Chapter III. For the purpose of maximization, the processes that are done exactly once, the fixed processes, may be removed from the equation, so the objective function is strictly a function of the variable processes, with coefficients determined by the production functions and cost functions developed in Chapter III. Each crop, of course, has its own unique function and within each crop irrigated and dryland crops have different functions.

Equation (1-2) in the introduction shows the objective function for irrigated corn and is merely the summation of the functions developed in Chapter III. Each of the crops have similar functions, except the small grains are not functions of pesticide or cultivation.

Wolfe Algorithm

Production functions are best described by a quadratic (11, 6). This research will deal strictly with quadratic functions. The constraints on the maximum intensity of the process or energy constraints involving combinations of the processes are strictly linear. There are many excellent algorithms for the optimization of a quadratic function with linear constraints. Some are direct methods, modifying the linear programming technique with the objective function gradients such as the Quadratic Differential and Wolfe Algorithms. Others use iterative search techniques such as the Rosen Gradient Projection, Rosenbrock's Algorithm, or SUMT (17). For this problem, with five state variables and up to six constraints, there is no significant difference in the speed or accuracy of these algorithms. For this reason, the WOLFE algorithm was chosen because of its simplicity and the ease in which constraints may be added and changed.

The algorithm used in this research is a modified version of the WOLFE algorithm listed by Mize and Kuester (17). A complete listing of Subroutine WOLFE is in the Appendix.

The algorithm minimizes the objective function as follows:

$$\text{Minimize:} \quad Z = \underline{P}\ \underline{X} + \underline{X}^T\ C\ \underline{X} \tag{4-2}$$

$$\text{Subject to:} \quad \underline{A}\ \underline{X} \leq \underline{B}$$

$$\underline{X} \geq 0$$

where $\underline{P}$ is the vector of linear cost coefficients, $\underline{X}$ is the vector of state variables, in this case the amount of the variable processes, $\underline{C}$ is a symmetric matrix of the quadratic cost coefficients, A is the matrix of technological coefficients, and B is the vector of constraint limits. To maximize one need only to minimize the negative of the objective function.

The Wolfe algorithm augments the simplex tableau by appending the Kuhn-Tucker necessary conditions. (For a detailed explanation, the reader is encouraged to consult any general optimization text.) The algorithm then, by the simplex method obtains a solution which satisfies the augmented set of linear equations. The feasible solution satisfying these conditions gives the optimum solution directly (assuming the problem posed is convex). The augmented tableau with the necessary conditions included is:

$$\left[\begin{array}{c:c:c:c} -2\underline{C} & \underline{A}^T & -\underline{I} & 0 \\ \hdashline \underline{A} & 0 & 0 & \underline{I} \end{array}\right] \begin{bmatrix} \underline{X} \\ \underline{L} \\ \underline{U} \\ \underline{S} \end{bmatrix} = \begin{bmatrix} \underline{P}^T \\ \underline{B} \end{bmatrix} \qquad (4\text{-}3)$$

$$\underline{L} \geq 0, \quad \underline{U} \geq 0, \quad \underline{X} \geq 0, \quad \underline{S} \geq 0$$

$\underline{L}$ is the vector of lagrangian multipliers, $\underline{U}$ is the vector of objective function gradients, and $\underline{S}$ is the vector of constraint slack variables. With artificials, this gives 3n + 2m variables in the tableau with m + n variables in the basis. (n is the number of original state variables in $\underline{X}$, m is the original number of constraints.) In the output, only the values of the first n variables, the original state variables, are of interest.

Variable Process Optimization

Subroutine WOLFE, with its associated subroutines accomplishes the optimal assignment of the variable processes, maximizing the objective function described in the previous section for each crop and each year simulated. In each year's simulation, WOLFE is called fourteen times by subroutine CROPQ. The information passed includes the crop code the current price of the crop, a code for irrigated land or dry land, and the current price for petroleum, natural gas, and electricity.

Subroutine WOLFE passes the crop codes and energy price to subroutine DATAN which assigns the appropriate elements of the $\underline{P}$ vector and $\underline{C}$ matrix for the specific crop. These cost coefficients are a function of energy prices. Typical of this assignment, the $\underline{P}$ and $\underline{C}$ elements for irrigated corn (the objective function described by Equation (1-2)) are:

$$\underline{C} = \begin{matrix}\text{current}\\ \text{corn}\\ \text{price}\end{matrix} \times \begin{bmatrix} 0.00065 & 0 & 0 & 0 & -0.00035 \\ 0 & 2.75 & 1.00 & 0 & 0 \\ 0 & 1.00 & 2.40 & 0 & 0 \\ 0 & 0 & 0 & 29.4 & 0 \\ -0.00035 & 0 & 0 & 0 & 0.11 \end{bmatrix} \tag{4-4}$$

$$\underline{P} = \begin{bmatrix} -0.33 \times \frac{\text{corn}}{\text{price}} + 0.068 \times ADJ + 0.012 \times EC(1) + 0.015 \\ \times EC(2) + 0.64 \times EC(3) \\ -11.6 \times \frac{\text{corn}}{\text{price}} + 3.08 \times ADJ + 0.132 \times EC(1) + 0.038 \\ \times EC(2) + 0.51 \times EC(3) \\ -13.1 \times \frac{\text{corn}}{\text{price}} + 0.98 \times ADJ + 0.32 \times EC(1) \\ -48.9 \times \frac{\text{corn}}{\text{price}} + 7.32 \times ADJ + 0.132 \times EC(1) + 0.038 \\ \times EC(2) + 0.51 \times EC(3) \\ -4.9 \times \frac{\text{corn}}{\text{price}} + 0.33 \times ADJ + 0.78 \times EC(1) + 0.07 \\ \times EC(2) + 21.33 \times EC(3) \end{bmatrix} \tag{4-5}$$

ADJ = inflation adjustment factor for non-fuel costs of labor, equipment repair, interest and insurance.

EC(1) = price of 1 gallon of petroleum (average of gasoline, diesel, and liquid petroleum).

EC(2) = price of 1000 ft.^{3} of natural gas.

EC(3) = price of 1 kilowatt hour of electricity.

The state variables are, respectively: (1) fertilizer, pounds per acre; (2) herbicide, pounds per acre; (3) cultivation, times over; (4) pesticide, pounds per acre; and (5) irrigation, inches per acre. The only cross-products are between irrigation and fertilizer and herbicide and cultivation. Since $X_{ij} = X_{ji}$ the off diagonal terms each are half of the cross-product. Since the algorithm minimizes, the signs of $\underline{C}$ and $\underline{P}$ are reversed.

Subroutine DATAN returns the parameter n, and the objective function linear and quadratic terms to subroutine WOLFE. To complete the mathematical statement, the number of constraints, m, and the constraint coefficients $\underline{A}$ and $\underline{B}$ are required. These are supplied to WOLFE from subroutine CONST. WOLFE supplies the number of variables, n, and the crop codes and CONST returns the number of constraints m, and the coefficients of $\underline{A}$ and $\underline{B}$. The technological coefficients of $\underline{A}$ are explicitly written for each crop. The basic program provides constraint coefficients for each of the three energy types. The right hand side vector, representing the maximum allowed energy is read in as data provided by the user for each crop and each year (fourteen cards each with three upper limits per year's simulation). Additional resource constraints and upper limits must be explicitly added to subroutine CONST.

As an example, the constraints on corn are shown below. The first three are for petroleum, natural gas, and electricity. The fourth is a typical resource constraint, on fertilizer in this case.

$$\underline{A} = \begin{bmatrix} 0.012 & 0.132 & 0.32 & 0.132 & 0.78 \\ 0.015 & 0.038 & 0.0 & 0.038 & 0.07 \\ 0.64 & 0.51 & 0.0 & 0.51 & 21.33 \\ 1.0 & 0.0 & 0.0 & 0.0 & 0.0 \end{bmatrix} \tag{4-4}$$

$$\underline{B} = \begin{bmatrix} \text{user supplied} \\ \text{user supplied} \\ \text{user supplied} \\ 200.0 \end{bmatrix} \tag{4-7}$$

The user supplied upper limits represent the total energy allowed, minus that used for the fixed processes, as shown in Chapter III. The coefficients of the energy constraints represent the amount of that specific type of energy used for one unit of that process. For example, it takes 21.33 kwh of electricity, 0.07 MCF of natural gas, and 0.78 gallons of petroleum for one acre-inch of irrigation of corn.

Subroutine CONST, then, returns to WOLFE the number of constraints and their coefficients. Subroutine WOLFE then optimizes the processes subject to the stated constraints and returns the optimal values back to CROPQ.

Subroutine CROPQ combines the variable product intensities for dry and irrigated land for each crop and writes out, at each iteration, the weighted average of crop intensity, representing the aggregate figures, for all seven crops. The weighting factors are the fraction of dryland and irrigated land, which is a linear function of the intensity of irrigation for each crop.

Yield, Costs, and Energy

Subroutine STAT

The final operation in the optimization and energy section is accomplished by subroutine STAT. CROPQ passes the optimal values of the variable process intensities to STAT. These values are used to determine yield, energy usage, and variable expenses.

The yield calculation is a composite of the production functions derived in Chapter III. The yield for each of the seven crops under dry and irrigated conditions is calculated separately. The expression for dryland corn is:

$$\begin{aligned} \text{YIELD} = {} & 19.6 + 0.33\ F - 0.00065\ F^2 + 13.1\ C - 2.40\ C^2 \\ & + 11.6\ H - 2.75\ H^2 - 2.00\ HC + 48.9\ P - 29.6\ P^2 \end{aligned} \tag{4-8}$$

For irrigated corn:

$$\begin{aligned} \text{YIELD} = {} & -12.1 + 0.33\ F - 0.0065\ F^2 + 4.9\ I - 0.11\ I^2 \\ & +0.0007\ FI + 13.1\ C - 2.40\ C^2 + 11.6\ H - 2.75\ H^2 \\ & -2.00\ HC + 48.9\ P - 29.6\ P^2 \end{aligned} \tag{4-9}$$

YIELD = bushels per acre of corn,

F = pounds of fertilizer per acre,

I = inches of irrigated water per acre,

H = pounds of herbicide per acre,

C = times over, cultivation, and

P = pounds of pesticide per acre.

The constant term reflects the yield at the 1972 aggregate variable process level rather than a true "zero input" level as discussed in the next section on validation.

The energy consumed in production of the crop commodities is calculated as the sum of the energy used per unit process times the intensity of that process. The fixed processes are a constant amount. The energy consumed in corn production (derived in Chapter III) is as follows:

$$\text{PETROLEUM} = 14.945 + 0.012\ F + 0.132\ H + 0.32\ C + 0.132\ P - 0.78\ I \quad \text{(gallons)} \tag{4-10}$$

$$\text{NATURAL GAS} = 0.78 + 0.015\ F + 0.038\ H + 0.038\ P + 0.07\ I \quad \text{(MCF)} \tag{4-11}$$

$$\text{ELECTRICITY} = 15.32 + 0.64\ F + 0.51\ H + 0.51\ P + 21.33\ I \quad \text{(KWH)} \tag{4-12}$$

As in the other calculations, the aggregate energy is obtained by weighting the irrigated and non-irrigated values.

The per acre costs include the cost of the energy used, and the non-energy costs of the fixed and variable processes. The equation used to calculate the costs of corn production is:

$$\begin{aligned}\text{VARIABLE COST} = {} & \text{(petroleum used)(price of petroleum)} \\ & + \text{(natural gas used)(price of natural gas)} \\ & + \text{(electricity used)(price of electricity)} \\ & + (10.964 + 0.068\ F + 3.08\ H + 0.98\ C + 3.08\ P \\ & + 0.33\ I)\ \text{ADJ} + (10.0)(0.214)\text{(price of corn)}\end{aligned} \tag{4-13}$$

ADJ is the inflation adjustment for the non-fuel costs, controlled by the user. The last part of the expression is the cost of seed per acre and is dependent on the current market price of the crop and the amount required per acre.

The cost, yield, energy, and process intensity of corn, sorghum, barley, and oats are combined in CROPQ on the basis of 1972 relative acreage to obtain the figures for the aggregate feed grain.

Model Validation

The validation of the original economic portion of the total model, POLYSIM, is well documented in the Technical Bulletin by Ray (22) and will not be repeated here. This is not to discount its importance, however. The accuracy of the dynamic price, supply, and demand response is dependent on the model validity.

The validation of the energy computations is difficult because of the lack of equivalent data. The recent congressional report generated in response to the mounting concern of the public about food and energy (37) does, however, on page 106, tabulate the fuel used in farming by crop. The technique used by the Economic Research Service is similar to that used in this research. A cross section of selected irrigated and non-irrigated crops was used to estimate the aggregate. Table XII shows a comparison of these estimates and of values generated in a single year using 1972 energy and crop prices and variable processes constrained in 1972 levels.

TABLE XII

FUEL USED IN CROP PRODUCTION

Crop	Gallons of Fuel Per Acre	
	Energy Model	E.R.S. Calculations
Wheat	11.44	11.13
Soybeans	12.48	22.87
Cotton	32.38	26.57
Corn	19.95	19.83
Sorghum	13.74	12.61
Oats	10.45	12.64
Barley	11.99	12.64

With the exception of soybeans, the figures are quite close. A possible reason for the difference in soybeans is the low percentage of irrigated land, 1.7%, determined in this research. There is no other reference to confirm or deny the source of the difference.

The energy and expense of petroleum consumption is at least as great as the energy and expense of natural gas and electricity consumption combined, for all crops. The statistics available on natural gas and electricity consumed in agriculture are aggregate figures for all crops and include household usage. The largest use of these categories of energy is in irrigation and drying and the accounting of these processes is quite straight forward with little chance of major error in accounting.

The calculation that has the greatest effect on the model performance is yield. The yield calculation, as described in the previous section, is a constant term and a function of the variable processes. The constant term is such that the yield is accurate at the normal variable input levels. The function of those inputs must accurately reflect the change in yield around that "normal" point.

The 1973 variable input levels were used in the yield equations of the energy model (subroutine STAT) and the results are compared with actual 1973 aggregate crop yields in Table XIII.

The functions of variable costs were determined at the same time and in the same manner as the energy calculations, as described in Chapter III. These costs not only affect the income of the producer, but also affect the intensity of variable inputs to production. A one year simulation was made using 1973-1974 energy and crop prices. The resulting variable cost calculations are compared with the 1974 baseline estimate by the U.S. Department of Agriculture, used in POLYSIM (Table IV).

TABLE XIII

CROP YIELDS

Crop	Model Calculations	1973 Actual
Wheat	31.13	32.7
Soybeans	27.94	28.0
Cotton	470.0	478.0
Corn	94.06	96.7
Sorghum	58.89	60.7
Oats	51.77	51.1
Barley	41.10	43.6

TABLE XIV

VARIABLE COSTS

Crop	Calculated	Baseline
Wheat	$ 32.45/acre	$ 32.12/acre
Soybeans	$ 37.00/acre	$ 33.88/acre
Cotton	$147.24/acre	$145.39/acre
Feed grains	$ 49.85/acre	$ 52.94/acre

CHAPTER V

ALTERNATE POLICIES AND FUTURES EVALUATION

The stated purpose of this research is to evaluate the impact of alternate energy policies and prices on food production and energy consumption by agriculture. The model described in the previous chapter is the vehicle for this evaluation.

The model has three independent methods through which decision variables may be changed to simulate a specific energy situation. These are: the price of natural gas, petroleum, and electricity for each simulated year, read in as data, the total amount of each type of energy used by the variable process in each year of simulation may be constrained to a maximum supplied by the user, and any one of the variable processes of any crop may be constrained to a maximum, supplied by the user. The technological coefficients (the amount of energy required by a unit of each variable process) of the energy constraints are inherent in the program. The constraint limits are read in as data. The process limiting constraints are added to subroutine CONST.

The model is constructed to allow change in non-energy related variables. These include the inflation rate of the non-energy expenses of the variable inputs: labor, interest, insurance, equipment repair, and the cost of the chemicals, less energy costs. Also, the market situation and government farm policy could be changed. These variables, however, will be the same for all simulations, set for the most reasonable situation so the various simulations will reflect the results of changes in energy prices and availability only.

This consistency of conditions for all simulations means the only difference for all simulations documented in this chapter are the three energy-related decision variables described earlier. All simulations are the five years 1975 through 1979 inclusive. The inflation for the non-energy portion of the cost of the variable processes, unless otherwise stated, is twelve per cent in 1973 and 1974 and eight percent thereafter. The government price support policy used for all simulations reflects the current policy: the use of target prices, with the prices adjusted annually, and loan rates to support market prices as needed. None of the baseline variables and estimates are preempted or changed for any of the simulations.

Baseline Simple Simulation

The first simulation is simple in that there are no energy or process constraints and optimistic in that energy prices increase only ten per cent annually during the simulation. The 1975 energy prices reflect the national average prices paid by farmers in December, 1974.

This simulation will be described in detail so that the simulations of more complex situations may be compared with this, the baseline simulation. The results of changes in energy price or availability are compared and contrasted in those areas where there is a significant change in one or more of the variables of interest.

Figure 4 shows the energy price and consumption, yields, costs, process intensities, and the fraction of land irrigated for each crop for each year of simulation. The yield is in bushels per acre, except cotton, which is in pounds lint per acre. Petroleum is the number of gallons of gasoline, L.P., and diesel fuel used per acre. Natural gas is in MCF and electricity is in KWH. Fertilizer, herbicide, and pesticide is in pounds per acre harvested. Cultivation is average times over. Irrigation is in acre-inches per irrigated acre and per cent irrigation is the fraction of harvested acreage that is under irrigation. The feed grain figures reflect a weighted average of corn, sorghum, oats, and barley.

Table XV shows the crop prices received by the grower over the simulation period. Table XVI shows the harvested acreage over the simulation period.

The baseline simulation begins in 1975. 1974 price information is shown since it is used in the 1975 optimization and other calculations. The 1975 crop prices, with the

YEAR: 1975

PETROLEUM PRICE $ 0.406/GALLON

NATURAL GAS PRICE $ 0.746/MCF

ELECTRICITY PRICE $ 0.027/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	34.05	37.56	11.96	1.29	72.27	67.07	0.52	1.68	0.0	26.81	0.05
SOYBEANS	27.67	32.14	12.74	0.15	38.38	34.48	0.47	2.85	0.18	21.00	0.01
COTTON	478.53	139.83	30.88	2.85	147.56	83.61	1.18	4.12	5.55	23.89	0.17
CORN	104.70	67.33	19.71	4.36	191.71	227.22	1.12	2.16	0.78	20.05	0.07
SORGHUM	58.35	40.84	13.36	2.99	91.75	123.82	0.77	2.16	0.0	20.10	0.05
OATS	56.26	28.97	10.04	0.49	51.31	51.30	0.56	1.95	0.0	15.22	0.03
BARLEY	41.78	32.22	11.91	0.62	34.72	37.77	0.55	1.99	0.0	13.31	0.03
FEED GRAIN	84.46	54.30	16.58	3.21	140.70	167.18	0.93	2.11	0.48	18.64	

YEAR: 1976

PETROLEUM PRICE $ 0.446/GALLON

NATURAL GAS PRICE $ 0.821/MCF

ELECTRICITY PRICE $ 0.030/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	33.02	35.40	10.99	1.10	44.54	60.91	0.43	1.68	0.0	12.50	0.03
SOYBEANS	27.28	29.97	12.59	0.13	34.30	33.16	0.14	2.87	0.17	16.02	0.01
COTTON	468.69	149.67	30.69	2.78	142.18	80.25	1.17	4.12	5.35	23.45	0.16
CORN	102.68	64.09	19.27	3.95	172.19	200.94	0.89	2.17	0.73	19.17	0.07
SORGHUM	57.01	38.27	13.20	2.80	87.58	115.35	0.28	2.12	0.0	20.30	0.05
OATS	53.97	26.44	9.90	0.38	41.35	38.61	0.37	1.95	0.0	15.05	0.03
BARLEY	40.63	29.62	11.73	0.44	26.18	25.85	0.47	1.99	0.0	12.95	0.03
FEED GRAIN	82.59	51.32	16.25	2.90	125.91	146.93	0.69	2.11	0.45	18.08	

Figure 4. Baseline Simulation

YEAR: 1977

PETROLEUM PRICE $ 0.497/GALLON

NATURAL GAS PRICE $ 0.903/MCF

ELECTRICITY PRICE $ 0.032/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	33.26	39.47	11.17	1.14	49.73	62.35	0.45	1.68	0.0	16.05	0.03
SOYBEANS	27.09	31.33	12.52	0.12	32.61	32.70	0.03	2.87	0.17	13.20	0.01
COTTON	465.22	161.59	30.62	2.76	139.96	79.13	1.17	4.12	5.28	23.23	0.16
CORN	102.17	68.42	19.18	3.87	168.43	196.24	0.86	2.17	0.73	18.91	0.07
SORGHUM	56.68	40.80	13.17	2.77	86.86	113.84	0.20	2.12	0.0	20.34	0.05
OATS	53.00	27.63	9.67	0.34	33.77	36.30	0.34	1.95	0.0	9.50	0.02
BARLEY	40.15	31.16	11.52	0.39	19.88	23.69	0.46	1.99	0.0	7.40	0.01
FEED GRAIN	82.04	54.65	16.13	2.84	121.77	143.29	0.65	2.11	0.44	16.55	

YEAR: 1978

PETROLEUM PRICE $ 0.540/GALLON

NATURAL GAS PRICE $ 0.993/MCF

ELECTRICITY PRICE $ 0.036/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	32.97	41.44	10.94	1.10	43.24	60.71	0.42	1.68	0.0	11.36	0.02
SOYBEANS	27.11	34.04	12.53	0.12	32.68	32.74	0.04	2.87	0.17	13.28	0.01
COTTON	503.12	183.14	31.32	3.05	160.45	93.22	1.20	4.13	6.16	24.79	0.17
CORN	102.40	74.75	19.22	3.90	170.02	198.24	0.87	2.17	0.73	19.02	0.07
SORGHUM	56.84	44.63	13.19	2.78	87.14	114.42	0.24	2.12	0.0	20.32	0.05
OATS	53.38	30.38	9.74	0.35	36.35	37.27	0.35	1.95	0.0	11.54	0.02
BARLEY	40.32	34.13	11.58	0.41	21.72	24.59	0.47	1.99	0.0	9.13	0.02
FEED GRAIN	82.28	59.75	16.18	2.86	123.34	144.83	0.67	2.11	0.44	17.08	

Figure 4. (Continued)

THE MARKET PRICE OF 28 IN 1978WAS $ 0.400
CROP NO. 28 IN YEAR 1978 NEW PRICE IS, 0.41 STOCKS BOUGHT ARE, 0.19

YEAR: 1979

PETROLEUM PRICE $ 0.594/GALLON

NATURAL GAS PRICE $ 1.092/MCF

ELECTRICITY PRICE $ 0.039/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	32.83	44.34	10.85	1.07	40.56	59.92	0.41	1.68	0.0	8.80	0.02
SOYBEANS	27.26	38.14	12.57	0.12	33.90	33.11	0.13	2.87	0.17	15.25	0.01
COTTON	394.39	176.77	29.61	2.33	110.64	59.16	1.12	4.10	4.04	20.79	0.15
CORN	102.21	80.62	19.18	3.88	168.49	196.48	0.86	2.17	0.73	18.88	0.07
SORGHUM	56.72	48.15	13.18	2.77	86.87	113.86	0.22	2.12	0.0	20.34	0.05
OATS	53.02	32.48	9.65	0.34	33.34	36.45	0.34	1.95	0.0	8.80	0.02
BARLEY	40.16	36.61	11.51	0.39	19.64	23.84	0.46	1.99	0.0	6.84	0.01
FEED GRAIN	82.08	64.39	16.13	2.84	121.72	143.48	0.65	2.11	0.44	16.37	

Figure 4. (Continued)

TABLE XV

BASELINE SIMULATION CROP PRICES

Year	Corn $/Bu.	Wheat $/Bu.	Soybeans $/Bu.	Cotton $/lb.
1974	3.10	4.10	6.25	0.40
1975	1.89	2.34	3.83	0.41
1976	1.87	2.86	3.60	0.44
1977	2.11	2.71	3.95	0.58
1978	2.22	2.77	4.80	0.41
1979	2.32	2.82	6.09	0.64

TABLE XVI

BASELINE SIMULATION HARVESTED ACREAGE

	Crop - Millions of Acres			
Year	Feed Grains	Wheat	Soybeans	Cotton
1974	100.70	65.50	52.50	12.60
1975	102.60	67.50	55.50	9.40
1976	103.09	64.16	55.92	9.88
1977	103.65	63.41	54.55	10.09
1978	105.07	62.02	53.55	12.27
1979	107.31	62.18	56.22	9.72

exception of cotton, were at an all time high. They had risen at a much higher rate over 1973 than the costs of production, so one would expect the growers to use more of the variable inputs, producing higher yields. This is, in fact, the case. Simulated fertilizer use in 1975 is up from the 1973 actual use (36), from ten per cent for soybeans to 30 per cent for wheat. Cotton fertilizer use decreased due to lower crop price. Similar increases are seen in herbicide use, again for all crops except cotton.

Irrigation is the one notable exception to the 1975 increase in variable inputs to most crops. Chapter III showed the energy input to all processes. Irrigation is shown to be the most energy intensive process of the five variable processes. As such, it has experienced the highest cost increase and where it is of marginal benefit, in the small grains, there is actually a slight decrease in the amount of irrigation per acre.

Considering the levels of all of the processes in 1975 (Figure 4), it appears that fertilizer and herbicide use is most sensitive to crop price charges, while cultivation and pesticide are less sensitive. The effect on irrigation varies with the crop. The aggregate effect on yield varies. Table XVII compares 1975 simulated yields with base data yield for 1975.

A year with high yields, as simulated in 1975 affects the market by driving the price of the commodity down. This is shown dramatically in Table XV. The price of corn drops from \$3.10 to \$1.89, wheat drops from \$4.10 to \$2.34, and soybeans drop from \$6.25 to \$3.83. Cotton price is relatively stable with average production for the year.

TABLE XVII

SIMULATED AND BASE DATA YIELDS, 1975

	Feed Grains tons/acre	Wheat bu/acre	Soybeans bu/acre	Cotton lbs./acre
Simulated	2.25	34.06	27.68	486.09
Base Data	2.11	31.50	27.03	500.43

The 1976 outlook for producers is lower crop prices and higher energy and non-energy prices. This reduces the amount of variable inputs the producer will use to maximize his net income, which will in turn lower the yields. The simulated yields in 1976, from Figure 4, are down: one bushel/acre in wheat and two in feed grain. Variable costs are down in most categories in spite of increasing costs. The reduced levels of inputs, in most cases, more than offset the effects of inflation.

Energy use is down from 1975 for all crops and all energy, due to reduced inputs. Electricity use is down significantly, due primarily to the reduction of irrigation, and acres under irrigation, of small grains. Wheat, oats, and barley are shown to use much less irrigation in 1976. The squeeze between higher expenses and lower crop prices will hit hardest where the net profit is marginal. Irrigation of small grains, while expensive and high energy consuming, does not increase the crop value as much as other inputs, or the irrigation of row crops, and is the first input to be reduced when grain prices drop and energy prices increase.

Natural gas consumption is reduced ten per cent in 1976, due not only to irrigation reduction, but reduced levels of fertilization and herbicides as well. Fertilization is about ten per cent reduced and the herbicide usage level is 20 per cent lower.

Petroleum use per acre has decreased only slightly in 1976. Most of the uses of petroleum are non-varying, or little varying: transportation, harvest, planting, preplanting tillage, drying, and cultivation. Little is used in chemical production or in irrigation.

In a continuing situation where expenses are rising and crop prices falling, yields will decrease until the price begins to rise again and without any perturbation of a random nature, weather for example, yield should stabilize and crop prices increase in proportion to production expenses. This effect is seen in the baseline simulation. In general, except for cotton, yields have stabilized in 1977 and prices begin a gradual increase. This trend continues as there are no further step changes in the base data or in energy price or availability.

Cotton yields react dramatically to the sharp changes in price from 1976 to 1979. The change is initiated by a series of considerable changes in the base data prediction of harvested acreage. The predicted harvested acreage for 1977 through 1979 is 9.50, 11.70, and 9.90 million acres, respectively. The effect of this change along with changes in yields due to price change make cotton production vary greatly, adding to the oscillating prices. This shows that cotton yield is very sensitive to changes in expected crop price.

The most significant change through the simulation period is the drastic reduction in irrigation of small grains. As mentioned above, the cost of irrigation can be expected to rise as rapidly as energy, while the benefits are not great for small grains, and becomes less profitable if crop prices do not show the rapid increase that energy shows.

Total production expenses, realized net farm income, total consumers expenditure, and total government payments for the simulation period are shown in Table XVIII. Total consumer expenditures include livestock expenditures. Similarly net farm income is from all sources: crop and livestock and government payments.

TABLE XVIII

BASELINE SIMULATION EXPENSES AND INCOME

Year	Total Consumers Expenditure $ Million	Total Government Payments $ Million	Total Production Expenses $ Million	Realized Net Farm Income $ Million
1974	147,586	273	75,246	26,757
1975	158,132	732	75,558	19,277
1976	165,375	420	82,392	15,494
1977	177,739	471	86,972	17,353
1978	190,821	857	93,725	20,796
1979	202,547	389	99,297	22,880

Not surprisingly, the net farm income follows the trend of the crop prices: initially dropping due to good yields, then picking up as production decreases and crop prices begin increasing with production expenses.

Simulating Increasing Energy Costs

Many events, controllable and uncontrollable, could occur in the next several years that would have a dramatic and immediate effect on the price of natural gas, petroleum, and electricity. A large step increase in petroleum price could come as a result of a jump by producers, a tarriff on imported oil, or de-regulation of domestic oil. A large increase in natural gas price would occur if interstate sales price was de-regulated. Electricity price is tied to the other energy sources. Several examples of these situations have been simulated.

The de-regulation of natural gas would result in an immediate price increase. A simulation was made of this situation by assuming the price of natural gas, which was \$.75/MCF in 1975 increased to \$1.30/MCF in 1976 and remained constant through 1979. The effect was shown by a 20% increase in electricity in 1977, otherwise electricity and petroleum increased ten per cent annually. It is assumed no shortages result from the de-regulation.

Comparison of this simulation with the baseline simulation in 1977, when the effect of the increased price of electricity is felt, shows several changes. The biggest effect is, not surprisingly, in irrigation. In 1977 the average intensity of irrigation was reduced approximately one acre-inch from the baseline simulation results. In addition, fertilizer use was reduced one to two per cent from the baseline results. The effect of these reductions in 1977 is a two per cent decrease in the consumption of natural gas and a one to two per cent increase in the cost per acre. The effect on yields in 1977 is observable, but not significant; in general, less than one-half of one per cent decrease.

These effects are of such low magnitude they would probably be hidden by random effects. They do, however, show the demand elasticity of natural gas in the agriculture sector. In 1977 there is a \$.40/MCF price difference between this simulation and the baseline simulation. The effects are less pronounced in 1978 and 1979 as the predicted natural gas price of the baseline simulation approaches the \$1.30 figure used in this simulation and the prices received for crops are a few cents higher in the last three years of the simulation of de-regulation.

Table XIX shows the variable costs for feed grains and the net farm income for the baseline and natural gas de-regulation simulation. The yields and crop prices are not shown as the differences, as described in the previous paragraph, are small. From the table, it is apparent that the consumers and the government paid for most of the increased cost of production, but, again it would be of such a small magnitude that it would not be noticed.

TABLE XIX

VARIABLE COSTS AND NET FARM INCOME—DE-REGULATED NATURAL GAS

Year	Variable Costs (feed grains) \$/Acre		Net Farm Income \$ Million	
	Base	Dereg.	Base	Dereg.
1975	54.30	54.30	19,217	19,217
1976	51.32	51.79	15,494	15,456
1977	54.64	55.78	17,353	17,320
1978	59.75	60.79	20,796	20,791
1979	64.39	65.16	22,880	22,932

Either domestic or foreign action could increase the price of petroleum rapidly. The simulation of the effect of a sudden increase in petroleum price was made under the following assumptions: in 1976 the price of petroleum delivered to food growers rises to $0.75/gallon, accompanied by a $0.011/KWH increase in electricity, and continues to rise at ten per cent annually. Natural gas price is the same as the baseline simulation, increasing at ten per cent. There are no process or energy limitations or shortages.

In 1975 the simulated conditions are the same as the baseline simulation so the results are identical. In 1976, when the petroleum and electricity prices experience a rapid increase, several effects are immediately noticeable. Irrigation, particularly of small grains, has been previously shown to be very sensitive to energy price charges. Over three-fourths of the irrigation uses petroleum or electricity as pump energy so the effect is considerable. Table XX shows the irrigation amount and fraction of land irrigated for this simulation and the baseline simulation in 1976.

The increased price of energy in this simulation makes it no longer profitable to irrigate small grains. Intensity of cultivation and fertilizer is down approximately one per cent in 1976 from the baseline simulation. Herbicide and pesticide use remains the same.

TABLE XX

1976 IRRITATION — HIGH PETROLEUM PRICE

Crop	Baseline Simulation Irrigation acre-inch	Baseline Simulation Fraction Irrigated	High Petroleum Irrigation acre-inch	High Petroleum Fraction Irrigated
Wheat	12.50	0.03	0.0	0.0
Soybeans	16.02	0.01	12.20	0.01
Cotton	23.45	0.16	21.73	0.15
Corn	19.17	0.07	18.27	0.06
Sorghum	20.30	0.05	20.33	0.05
Oats	15.05	0.03	0.0	0.0
Barley	12.95	0.03	0.0	0.0

The aggregate effect of these resource reductions is reduced energy usage, especially in small grains, increased variable costs, and yields reduced one-half to one per cent. The greatest energy reduction is in electricity. It is down ten per cent from the baseline simulation, due to the reduced irrigation level. Petroleum use is down one to two per cent. Most uses of petroleum are relatively inelastic with respect to price. Table XXI shows the effect on yield, variable costs, and price of wheat. Other crops show similar but reduced effects.

The variable costs for all crops run approximately ten per cent higher than in the baseline simulation after 1975.

TABLE XXI

YIELD, VARIABLE COSTS, AND PRICE OF WHEAT — HIGH PETROLEUM PRICE

Year	Yield Bu/Acre		Variable Cost $/Acre		Price $/Bu	
	Base	High Petr.	Base	High Petr.	Base	High Petr.
1975	34.05	34.05	39.56	39.56	2.34	2.34
1976	33.02	32.75	37.40	40.83	2.86	2.91
1977	33.26	33.02	41.47	44.42	2.71	2.80
1978	32.97	32.77	43.44	46.41	2.77	2.76
1979	32.83	32.68	46.35	49.06	2.82	2.81

This is to be expected, since over half of the variable costs are due to direct or indirect use of energy. The harvested acreage of the crops was not significantly altered. From Table XXII it appears the grower bears most of the additional costs of production. Government payments (not shown) show no increase.

TABLE XXII

CONSUMER EXPENDITURE AND NET FARM INCOME — HIGH PETROLEUM PRICE

Year	Total Consumer Expenditure $ Million		Net Farm Income $ Million	
	Base	High Petr.	Base	High Petr.
1975	158,132	158,132	19,217	19,277
1976	165,375	165,375	15,494	14,991
1977	177,739	178,028	17,353	17,032
1978	190,821	191,091	20,796	20,422
1979	202,547	202,750	22,880	22,546

The worst case of price increases would be to have all of the previous effects together, causing all energy to increase in price rapidly. A simulation was made of this situation. Energy prices increase rapidly and linearly from 1975 to 1979. Petroleum is assumed to go from $0.40 to

$0.90 per gallon, natural gas from $0.75 to $1.50/MCF, and electricity from $0.027 to $0.045/KWH. Again, no shortages or limitations are anticipated.

Spreading the price increases over the entire simulation period does not have quite the sharp effect on any one year that the step increases have shown. By increasing input prices incrementally each year, prices, yields, and harvested acreage for all crops undergo no great changes from the baseline simulation. In 1976 there is, as in the other simulations of higher energy prices, a decrease in the irrigation of small grains. Irrigation has, in fact, been reduced 50 per cent for wheat, oats, and barley in 1976. This is the chief cause of a slight decrease in yields and energy consumed, and with higher energy prices, the variable costs have increased slightly.

In 1977, prices are higher, seven cents for wheat and one cent for corn. The increase in wheat price keeps irrigation of wheat profitable in spite of the rising energy costs. Barley and oats, competing with corn, do not experience a price increase and are squeezed by rising energy costs, so that irrigation is not profitable at all. In 1977 the simulation of the rapid energy price increases show variable costs to be five per cent higher, yields and energy use down less than one per cent from the baseline simulation due mostly to reduced irrigation.

As the price of energy grows, the difference in variable costs between this simulation and the baseline simulation grows to ten per cent in 1979. Overall, yields are reduced one-half to one per cent due to the reduced irrigation (in fact eliminated for wheat, oats, and barley) and a two to four per cent reduction in fertilizer levels. Energy use is one per cent for petroleum and natural gas and four per cent for electricity, again because of reduced irrigation.

Table XXIII shows that total production and price of wheat to be affected by the rapid price increase more than the feed grains. Soybeans were affected even less than feed grains because of an initial low fraction of irrigated land.

As in the previous simulations of higher energy prices, the additional costs of production have been borne primarily by the farm sector. In this simulation in 1979 the production expenses are $700 million higher than the baseline simulation figure. The government payments that year are $22 million more, the total consumer expenditure is $140 million more, but the net farm income is down by $660 million.

It is appropriate for this area of investigation to show the general effects of inflation, both energy and non-energy, on food production. Yield, variable costs, energy use and price will certainly be changed. Further, consumer spending and farm income are of importance.

To point out these effects, two simulations were made of the two extremes: the first assuming an inflation rate of ten per cent for energy and two per cent for non-energy, the

TABLE XXIII

PRODUCTION AND PRICE, WHEAT AND FEED GRAIN, RAPID ENERGY PRICE INCREASE

Year	Wheat				Feed Grain			
	Production Bu x 10^6		Price $/Bu		Production tons x 10^6		Price $/Bu Corn	
	Base	High Energy	Base	High Energy	Base	High Energy	Base	High Energy
1975	2298	2298	2.34	2.34	230.5	230.5	1.89	1.89
1976	2118	2112	2.86	2.88	226.5	226.1	1.87	1.88
1977	2109	2100	2.71	2.78	226.2	225.6	2.11	2.12
1978	2044	2044	2.77	2.75	230.0	229.6	2.22	2.23
1979	2041	2029	2.82	2.82	234.3	233.4	2.32	2.34

second assuming twenty per cent for energy and ten per cent for non-energy.

As in the other simulations of high inflation, the crop prices do not keep up with the high rate of inflation, causing reduced inputs, yields, and energy use, with increased variable costs and crop prices. The magnitude of the changes vary from crop to crop, affecting soybeans the least and cotton the most. Tables XXIV and XXV show the yield, variable expense, and crop price for wheat and cotton.

It appears from Tables XXIV and XXV that although the price the farmers receive is somewhat higher, the gross income per acre remains constant while costs are much higher with the high inflation rate. This is illustrated further by Table XXVI, showing the production expenses, consumer expenditures and net income for both inflation rates. The reduction in energy usage, particularly electricity is similar to that simulated for rapid increases in energy costs.

Simulating Energy Limitations

There is a very real possibility that energy will be in short supply in the future. The oil embargo of 1973 saw petroleum allocated at reduced levels. Natural gas reserves are dwindling yearly, threatening a shortage. It is unlikely, however, that electricity would be reduced except on rare occasions during peak demand. A simulation of the market

TABLE XXIV

INFLATION AND WHEAT PRODUCTION

Year	Yield Bu/Acre Low	Yield Bu/Acre High	Variable Cost $/Acre Low	Variable Cost $/Acre High	Crop Price $/Bu Low	Crop Price $/Bu High
1975	34.05	34.05	39.56	39.56	2.34	2.34
1976	33.09	32.91	36.14	38.28	2.85	2.88
1977	33.37	33.06	38.73	43.45	2.69	2.78
1978	33.14	32.70	39.20	46.97	2.74	2.77
1979	33.06	32.56	40.40	51.74	2.78	2.83

TABLE XXV

INFLATION AND COTTON PRODUCTION

Year	Yield lbs. lint/acre Low	Yield lbs. lint/acre High	Variable Cost $/Acre Low	Variable Cost $/Acre High	Crop Price $/lb. lint Low	Crop Price $/lb. lint High
1975	478	478	143.56	143.56	0.41	0.41
1976	480	463	148.09	156.68	0.43	0.45
1977	481	457	152.96	173.01	0.55	0.59
1978	517	495	165.56	201.13	0.41	0.41
1979	461	354	158.80	195.24	0.56	0.69

TABLE XXVI

INFLATION, EXPENSES, AND INCOME

Year	Production Expenses $ Million		Consumer Expense $ Million		Net Farm Income $ Million	
	Low	High	Low	High	Low	High
1975	75,559	75,559	158,132	158,132	19,277	19,277
1976	82,126	82,602	165,375	165,375	15,765	15,313
1977	86,335	88,049	177,598	177,889	17,702	17,080
1978	92,652	94,654	190,481	191,142	21,347	20,287
1979	98,012	100,544	202,094	203,030	23,624	22,174

under the conditions of oil shortage and natural gas shortage was made.

To simulate the oil shortage, total petroleum use was limited from 1976 to 1979, for each crop, to 95 per cent of the 1973 level. Dryland and irrigated crops were limited separately. All energy prices were allowed to increase at ten per cent.

In 1969 the simulation predicts large reductions in irrigation, fertilizer, and cultivation of row crops. Small grain yields are down, not because of the petroleum limitation as the fact that it is uneconomical to irrigate or fertilize at the 1975 rate. Energy use in 1976 is five to ten per cent below the baseline simulation.

Feed grain yield is most sensitive to the reduction of inputs due to constrained petroleum. After 1976 the price rises, but yields cannot increase due to the petroleum shortage. Table XXVII shows the yield, production and price of feed grains of the baseline simulation and the constrained petroleum simulation.

It is interesting to note that the gross income per acre for feed grains has actually increased in spite of the reduced yield. This, coupled with increased acreage and reduced variable expenses, should mean greater net income for feed grain growers. Table XXVIII shows that this extra cost to livestock growers is borne by the consumer, who pays more and receives less.

TABLE XXVII

FEED GRAIN PRODUCTION WITH LIMITED PETROLEUM

Year	Yield Tons/Acre		Production Million Tons		Price $/Ton	
	Base	Limited	Base	Limited	Base	Limited
1975	2.25	2.25	230.51	230.51	65.95	65.95
1976	2.20	2.05	226.49	211.07	65.50	76.98
1977	2.18	2.05	226.21	216.13	73.67	87.69
1978	2.19	2.05	229.96	221.85	77.53	87.73
1979	2.18	2.05	234.28	226.24	81.23	87.93

TABLE XXVIII

LIMITED PETROLEUM: INCOME AND EXPENSES

Year	Production Expenses $ Million		Consumer Expense $ Million		Net Farm Income $ Million	
	Base	Limited	Base	Limited	Base	Limited
1975	75,558	75,558	158,132	158,132	19,277	19,277
1976	82,392	83,133	165,375	165,375	15,494	15,518
1977	86,972	88,088	177,739	181,372	17,353	20,479
1978	93,725	93,737	190,821	194,520	20,796	23,971
1979	99,297	99,813	202,547	205,184	22,880	25,074

A natural gas shortage would affect all dryland crops more or less uniformly. Those crops irrigating with natural gas as fuel would be severely limited. A simulation of this situation was made assuming that in 1977 a natural gas shortage reduced fertilizer output by 20 per cent and curtailed irrigation by 20 per cent. As before, energy prices are increased ten per cent each year.

In 1977 simulated natural gas consumption is down ten per cent from 1976 and remains down, due to the shortage, through 1979. Table XXIX shows the effect on yield that the shortage produces.

TABLE XXIX

NATURAL GAS SHORTAGE: YIELD

	Feed Grains ton/acre	Soybeans bu/acre	Wheat bu/acre	Cotton lb/acre
		1977		
Base	2.18	27.09	33.26	465.2
Limited	2.14	26.30	31.07	459.3
		1978		
Base	2.19	27.11	32.97	503.12
Limited	2.14	26.37	31.01	490.8
		1979		
Base	2.18	27.26	32.83	394.39
Limited	2.14	26.49	30.95	403.7

Predictably, crop prices, except for cotton, ran ten per cent higher in 1978 and 1979. Like the previous simulation of a shortage of petroleum, the higher price received more than compensates the grower for the reduced yield so his net income increases appreciably. Table XXX shows how the producer gains and the consumer loses in 1979.

TABLE XXX

NATURAL GAS SHORTAGE: PRODUCTION COSTS AND RECEIPTS, 1979

	Baseline $ Million	Limited Natural Gas $ Million
Total Variable Costs - All Crops	13,527	13,120
Total Crop Receipts	49,009	49,974
Total Variable Costs - Livestock	40,413	41,180
Total Livestock Receipts	65,430	66,597
Total Consumers Expenditure	202,547	204,082
Total Production Expenses	99,297	99,745
Net Farm Income	22,880	24,374

Simulating Resource Limitations

The production of physical resources, chemical and fertilizer, could be limited due to a reduced supply of energy or other raw materials to industry. To investigate the result of such a limitation one simulation was made limiting herbicide and pesticide to 1973 levels and another made limiting fertilizer to 1973 levels.

The first simulation, limiting herbicide and pesticide, assumes a ten per cent energy price inflation. The results are similar to those of the previous section where the variable inputs were reduced due to a shortage of energy. In general, yields are down two to three per cent over the simulation period for all crops. Prices are five per cent higher, making slightly higher levels of other inputs (fertilizer, irrigation, and cultivation) economically feasible, so that no significant energy or variable cost reduction is seen. Table XXXI, showing statistics on feed grain production is typical of all crops.

In the market, the consumers pay slightly more for grain, cotton, and livestock so that the farm income is higher under the conditions of the limited chemicals.

The simulation limiting fertilizer to 1973 levels was run under the same energy price assumptions as the baseline simulation. No other constraints were imposed on energy or resources.

There was very little effect on the yield of row crops. Predicted feed grain prices in the baseline simulation are never as high as the 1973 prices. The 1973 rate of fertilization approached optimal level in 1973, so with the lower

TABLE XXXI

LIMITED CHEMICALS: FEED GRAIN PRODUCTION

Year	Yield Ton/Acre		Variable Expense $/Acre		Price $/Ton	
	Base	Limited	Base	Limited	Base	Limited
1975	2.25	2.16	53.30	52.47	65.95	74.15
1976	2.30	2.14	51.32	51.43	65.50	74.32
1977	2.18	2.13	54.65	55.19	73.67	79.83
1978	2.19	2.13	59.75	59.71	77.53	81.76
1979	2.18	2.12	64.39	64.12	81.23	84.81

prices, the 1973 fertilizer level constraint imposed no real limitation.

Small grains were only slightly affected by the limitation of fertilizer. In 1973, wheat was fertilized at a rate optimum for $1.50 to $2.00/bushel grain. High exports that year drove prices considerably higher than that so, the rate is sub-optimal for the $4/bushel actual grain price. The expected wheat price throughout the simulation is $2.70 to $2.90, so the 1973 level is less than the level that produces the highest expected net income to the grower. It amounts to a wheat yield two to three per cent lower than the baseline simulation. Energy and variable production costs are only nominally reduced. The consumers expenditure is just slightly reduced. Similarly, net farm income is slightly reduced, due to reduced crop receipts.

Extensive use of herbicides and little or no cultivation is an alternate method of controlling weeds. A simulation was made of minimum tillage practice on corn, sorghum, soybeans, and cotton. Cultivation is limited to one time over. Energy prices are consistent with the baseline simulation. No other constraints were imposed.

The result of more herbicide and less cultivation is to use less petroleum, but, indirectly, more natural gas and electricity. The petroleum reduction ranges from 0.4 gallons/acre for corn to 1.05 gallons/acre for cotton. Natural gas and electricity use is up less than five per cent.

Table XXXII shows the 1975 yield, variable cost, and herbicide use for the minimum tillage model.

Grain yields are down three to eight per cent. Cotton yield is cut in half. Cotton requires extensive use of cultivation and herbicide to maintain current yields, so minimum tillage is not a worthwhile alternative. To maintain grain yields at the level accomplished by cultivating would require considerably more herbicide. At current herbicide prices, however, this would not be profitable to the grower. It is also quite unlikely the herbicide industry could treble their output to meet such a demand.

If herbicide costs were reduced significantly, or effectively increased, increased herbicide use would become feasible in the face of rapidly rising petroleum prices or in a period of petroleum shortages. The simulation of minimum tillage shows grain prices up by ten per cent, all of which is borne by the consumer.

TABLE XXXII

MINIMUM TILLAGE, 1977

Crop	Yield per acre		Variable Cost $/acre		Herbicide lbs/acre	
	base	limited	base	limited	base	limited
Soybeans	27.67	25.96	37.89	38.15	0.47	1.15
Corn	104.70	101.81	67.69	67.75	1.12	1.54
Sorghum	58.35	56.90	39.16	39.33	0.77	1.15
Cotton	478.50	186.60	143.56	139.53	1.18	1.68

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

In the previous chapter the results of simulations of three categories of situations were described: where, due to controlled or uncontrolled events, energy prices rise substantially, energy is unavailable in the quantities used in the past, and resources are limited due to a shortage of raw materials.

The results of the simulation of the general categories of situations are summarized below:

Increasing Energy Costs - No Shortages

Slightly reduced yields
Slightly higher crop prices
Higher variable costs
Slightly reduced farm income
Slightly reduced energy use
Similar results in high non-energy inflation

Energy Shortages

Substantially reduced yields
Substantially higher crop prices
Reduced variable expenses
Higher farm income, higher consumer expenditures, reduced consumption
Similar results for chemical shortages

Conclusions

Action by the government that has the effect of accelerating the price increase of energy such as deregulation of natural gas and oil or tarriffs on foreign petroleum products has only a moderate effect on farm expenses. Yields are slightly lower, due mainly to a reduction or cessation of irrigation, the most energy intensive of the variable processes. Energy use declines slightly with higher prices, again due mostly to a reduction in irrigation, and partially to a slightly reduced level of fertilizer and chemicals. The producer takes most of the increased variable expenses from his net income. Obviously some growers will be affected more than others. Those relying on irrigation and energy intensive processes will be hit the hardest.

A high non-energy inflation rate has the same effect on yield, expenses and farm income as the high energy inflation rate, but is felt more uniformly by the farm community.

Dwindling reserves with little economic incentive for future development (continued regulation) could lead to a long term shortage of energy. Certainly, another reduction of oil sold to the U.S. by foreign producers would create instant shortages. The result of limiting either petroleum or natural gas to agricultural users has a substantial effect on yield and crop prices. A five per cent reduction in petroleum usage, direct and indirect, could decrease yields as much as eight per cent, causing crop prices to rise as much as ten per cent. Limiting natural gas would have a similar result. The increased prices are paid by the consumer buying a refined part of the grains or buying livestock fed by the more expensive and less plentiful grain.

If resources, chemical or fertilizers, are limited, due to a shortage of raw materials, the result is much the same as if the variable inputs to food production were limited due to a shortage of energy. The yields are decreased, prices are increased and the consumer pays the bill.

The final simulation, simulating a minimum tillage situation demonstrated that at the current price of gasoline and herbicide, a massive program of minimum or no tillage is not economically feasible. As shown by the production functions of Chapter III, the herbicide application rate would have to be two to three times the current rate to maintain high yields. The cost would be considerable. The energy savings would amount to a half gallon of fuel per acre, less the indirect energy required to produce the herbicide. When herbicide price is reduced relative to gasoline and effectively increases, decreased cultivation and increased herbicide use will be justified.

Recommendations

If energy shortages can be predicted and averted by imposing higher energy prices, the impact on agriculture, yields and crop prices, would be much reduced. It has been shown that higher energy prices do not appreciably reduce farm output, while an energy shortage does, causing higher prices for grain and livestock. This should be a factor in determining a national price policy for energy, which in turn determines availability. Those growers who face a hardship because of high energy requirements should be given favorable tax considerations where food production is more critical than the energy it consumes.

Agricultural research should continue to search for ways of increasing production without increasing energy inputs. More hearty hybrids and less expensive or more effective herbicides to replace tillage are possible examples.

This research effort could be continued and expanded in several areas. The existing model could be used to determine the farm support program that would be best suited for a particular energy price and availability. There is also a need for better data on the national aggregate production functions, particularly in the areas of pesticides, herbicides, and cultivation, where current aggregate data is incomplete. Finally, the effects of the many possible energy conservation measures should be tested to determine their true effect on energy consumption and yield. For example, by estimating the effect of using the optimal tractor size for minimum fuel usage the cost function of the model could be changed and compared with the existing model, or the cost of hauling natural fertilizer compared with manufacturing chemical fertilizer. All reasonable conservation techniques should be tested and if practical, implemented. Our world has become too small to waste food or energy.

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APPENDIX

SOURCE LISTING OF MODEL PROGRAM

```
FCRTRAN IV G LEVEL  21                CROPQ              DATE = 75209          10/40/14

          SUBROUTINE CROPQ                                                      00082300
          INTEGER  FT(90),TITLE(20,20),LABEL(84,33),SKIP(8)    ,SUPSOY          00082400
          COMMON /CMAIN5/ FT     ,TITLE        ,LABEL,JUMP  ,SKIP       ,SUPSOY00082500
          COMMON /CGOVS/  ADJ(45), CONST(90), AY(16), EXG , IFLAG, JJ,IP, IG00082600
         1, IE, IS, LO,  J,I,   C(14,208), B(14,208), EXOG(14,135), E(150)  00082700
         2, IHOLD1, IHOLD2, AHOLD1, AHOLD2                                      00082800
          COMMON /CMAINO/ LOAN, FGEXP,FPRIC                                     00082900
          COMMON /CMAIN1/ YIELD(16,4),IAJLOT, ADJTG, IZ, IT, IX, IST            00083000
          COMMON/WOLF/X(26)
          DIMENSION ENERGY(3),CROP(14),EC(3),FAC(7),AR(7,10)
          DATA CROP/'WHEA','T   ','SOYB','EANS', 'COTT','ON  ','CORN','    '
         1,'SORG','HUM ','OATS','    ','BARL','EY  '/
       83 FORMAT ('0',20A4,/, 'HARVESTED ACRE WAS GREATER THAN MAVIMUM POSSI00083100
         1BLE HARVESTED ACRES SO SET EQUAL TO LATTER FOR  ',A4)                00083200
    12345 FORMAT(1H0, 'SUBROUTINE CROPQ  ENTERED')                              00083300
          WRITE(8,12345)                                                        00083400
          READ(5,3) (EC(M),M=1,3)
        3 FORMAT(8F10.0)
          WRITE(6,6)AY(I),EC(1),EC(2),EC(3)
        6 FORMAT(//'0',10X,'YEAR: ',A4,//3X,'PETROLEUM PRICE   $ ',F5.3,'/GA
         1LLON',//3X,'NATURAL GAS PRICE $ ',F5.3,'/MCF',//3X,'ELECTRICITY PR
         2ICE $ ',F5.3,'/KWH')
          IEXP=I-3
          ADJX=1.25*(1.08**IEXP)
          DO 1 JL=1,2
          ID=JL-1
       20 FORMAT(///,3X,'CROP',3X,'YIELD',4X,'VAR COST',4X,'PETROL',3X,'NAT
         1GAS',2X,'ELECT',7X,'FERT',5X,'HERB',4X,'CULT',4X,'PEST',3X,'IRRIG'
         2,3X,'PCT IRR')
          DO1 IC=1,7
          GO TO (11,12,13,14,15,16,17),IC
       11 EP=C(J,26)
          GO TO 2
       12 EP=C(J,27)
          GO TO 2
       13 EP=C(J,28)
          GO TO 2
       14 EP=0.0281*C(J,25)
          GO TO 2
       15 EP=0.0231*C(J,25)
          GO TO 2
       16 EP=0.0125*C(J,25)
          GO TO 2
       17 EP=0.0230*C(J,25)
        2 CONTINUE
          DO 4 M=1,5
        4 X(M)=0.
          CALL WOLFE(IC,ID,N,EC,EP,ADJX,FAC,I)
          IF (N.EQ.5) GO TO 33
          DO 32 KK=N,5
          NP1=KK+1
       32 X(NP1)=0.
       33 CONTINUE
          CALL STAT(X,XYIELD,ENERGY,XCOST,IC,EC,ADJX,EP)
          IC2=IC*2
          ICM=IC2-1
       10 FORMAT(/1X,2A4,2X,F6.2,3X,F6.2,5X,3(F6.2,3X),6(2X,F6.2))
          IF(ID.EQ.1) GO TO 30
```

```
      AR(IC,1)=XYIELD
      AR( IC,2)=XCOST
      AR( IC,3)=ENERGY(1)
      AR( IC,4)=ENERGY(2)
      AR( IC,5)=ENERGY(3)
      DO 40 K=1,5
      KK=K+5
   40 AR( IC,KK)=X(K)
      GO TO 1
   30 AR(IC,1)=AR(IC,1)*(1.-FAC(IC))+XYIELD*FAC(IC)
      AR(IC,2)=AR( IC,2)*(1.-FAC(IC))+XCOST*FAC( IC)
      AR( IC,3)=AR( IC,3)*(1.-FAC(IC))+ENERGY(1)*FAC(IC)
      AR( IC,4)=AR(IC,4)*(1.-FAC(IC))+ENERGY(2)*FAC(IC)
      AR(IC,5)=AR(IC,5)*(1.-FAC(IC))+ENERGY(3)*FAC(IC)
      DO 50 K=1,4
      KK=K+5
   50 AR(IC,KK)=AR(IC,KK)*(1.-FAC(IC))+X(K)*FAC(IC)
      AR(IC,10)=X(5)
    1 CONTINUE
      WRITE(6,20)
      DO 60 L=1,7
      IL=2*L
      ILM=IL-1
      WRITE(6,10)CROP(ILM),CROP(IL),(AR(L,K),K=1,10),FAC(L)
   60 CONTINUE
      C1=0.608
      C2=0.143
      C3=0.145
      C4=0.103
      XYIELD=C1*AR(4,1)+C2*AR(5,1)+C3*AR(6,1)+C4*AR(7,1)
      XCOST=C1*AR(4,2)+C2*AR(5,2)+C3*AR(6,2)+C4*AR(7,2)
      ENERGY(1)=C1*AR(4,3)+C2*AR(5,3)+C3*AR(6,3)+C4*AR(7,3)
      ENERGY(2)=C1*AR(4,4)+C2*AR(5,4)+C3*AR(6,4)+C4*AR(7,4)
      ENERGY(3)=C1*AR(4,5)+C2*AR(5,5)+C3*AR(6,5)+C4*AR(7,5)
      C(I,5)=XYIELD*0.0266
      C(I,6)=AR(1,1)
      C(I,7)=AR(2,1)
      C(I,8)=AR(3,1)
      C(I,13)=XCOST
      C(I,14)=AR(1,2)
      C(I,15)=AR(2,2)
      C(I,16)=AR(3,2)
      DO 70 K=1,5
      JJ=K+5
   70 X(K)=C1*AR(4,JJ)+C2*AR(5,JJ)+C3*AR(6,JJ)+C4*AR(7,JJ)
      WRITE(6,80)XYIELD,XCOST,ENERGY(1),ENERGY(2),ENERGY(3),(X(M),M=1,5)
   80 FORMAT(/1X,'FEED GRAIN',F6.2,3X,F6.2,5X,3(F6.2,3X),5(2X,F6.2))
      WRITE(6,90)
   90 FORMAT('1')
C IF LOAN RATE IS GREATER THAN LAST YEARS MKT.PRICE THEN LOAN RATE = T-100083500
C YEAR'S PRICE IN INFLUENCING ACREAGE,YIELD AND VARIABLE EXPENSE PER AC.00083600
      FGPRIC=0.0                                                        00083800
      WHPRIC=0.0                                                        00083900
      SOYPRC=0.0                                                        00084000
      COTPRC=0.0                                                        00084100
      IF(LOAN.EQ.0) GO TO 300                                           00083700
      IF (C(J,25).LT.EXOG(I,58)) FGPRIC=C(J,25)                         00084200
      IF (C(J,25).LT.EXOG(I,58)) C(J,25)=EXOG(I,58)                     00084300
```

```
0107          IF (C(J,26).LT.EXOG(I,55)) WHPRIC=C(J,26)                           00084400
C108          IF (C(J,26).LT.EXOG(I,55)) C(J,26)=EXOG(I,55)                       00084500
0109          IF(C(J,27) .LT. EXOG(I,12)) SOYPRC=C(J,27)                          00084600
C110          IF(C(J,27).LT.EXOG(I,12)) C(J,27)=EXOG(I,12)                        00084700
0111          IF (C(J,28).LT.EXOG(I,56)) COTPRC=C(J,28)                           00084800
C112          IF (C(J,28).LT.EXOG(I,56)) C(J,28)=EXOG(I,56)                       00084900
0113      300 CONTINUE                                                            00085000
C114          IF (C(I,1).NE.0.0 .AND.C(I,5).NE.0.0 .AND. C(I,9).NE.0.0) C(I,5)=C00085100
             1(I,9)/C(I,1)                                                        00085200
        C     FEED GRAIN HARVESTED ACREAGE                                        00085300
        C-THIS IS THE WAY WE HANDLE PREDETERMINED POLICY VARIABLES.IF READ A FG 00085400
        C ACREAGE CARD IT IS STORED IN C(I,1)AND THUS CAUSES CONTROL TO JUMP     00085500
        C USUAL ACREAGE CALCULATION.                                              00085600
C115          IF(C(I,1).NE.0.0) GO TO 330                                         00085700
C116          C(I,1)=(B(I,1)*(1.0+(E(1)*((C(J,25)-B(J,25))/B(J,25)))+(E(2)*((C(J00085800
             1,26)-B(J,26))/B(J,26)))+(E(3)*((C(J,27)-B(J,27))/B(J,27)))+(E(4)*(00085900
             2(C(J,28)-B(J,28))/B(J,28)))+(E(55)*EXOG(I,38))))+(1.0-ADJ(1))*(C(J00086000
             3,1)-B(J,1))                                                         00086100
        C-IF CALCULATED HARVESTED ACRES IS GREATER THAN MAXIMUM HARVESTED ACRES 00086200
        C THEN ACREAGE SET TO LATTER LEVEL.                                       00086300
C117          IF (C(I,1).GT.EXOG(I,79)) WRITE(6,83)(TITLE(1,K),K=1,20),AY(I)      00086400
0118          IF (C(I,1).GT.EXOG(I,79)) C(I,1)=EXOG(I,79)                         00086500
C119      330 CONTINUE
        C     FEED GRAIN PRODUCTION                                               00087000
0120      335 YIELD(I+2,1)   = C(I,5)                                             00087100
0121          IF(C(I,9).NE.0.0) GO TO 340                                         00087200
0122          C(I,9)=C(I,1)*C(I,5)                                                00087300
0123      340 CONTINUE                                                            00087400
0124          IF ((C(I,1)*C(I,5)).NE.C(I,9)) C(I,5)=C(I,9)/C(I,1)                 00087500
        C     FEED GRAIN SUPPLY                                                   00087600
0125          C(I,21)=C(I,9)+EXOG(I,2)+C(J,41) - C(J,150)                         00087700
        C     FEED GRAIN TOTAL PRODUCTION EXPENSES                                00088300
0126          C(I,17)=C(I,1)*C(I,13)                                              00088400
C127          IF (C(I,2).NE.0.0 .AND. C(I,6).NE.0.0 .AND. C(I,10).NE.0.0) C(I,6)00088500
             1=C(I,10)/C(I,2)                                                     00088600
        C     WHEAT HARVESTED ACREAGE                                             00088700
C128          IF(C(I,2).NE.0.0) GO TO 345                                         00088800
C129          C(I,2)= B(I,2)*(1.0+(E(8)*((C(J,26)-B(J,26))/B(J,26)))+(E(9)*((C(J00088900
             1,25)-B(J,25))/B(J,25)))+(E(10)*((C(J,27)-B(J,27))/B(J,27)))+(E(52)00089000
             2*((C(J,28)-B(J,28))/B(J,28)))+(E(56)*EXOG(I,38))) +(1.0-ADJ(2))*(C00089100
             3(J,2)-B(J,2))                                                       00089200
C130          IF (C(I,2).GT.EXOG(I,80)) WRITE(6,83)(TITLE(2,K),K=1,20),AY(I)      00089300
0131          IF (C(I,2).GT.EXOG(I,80)) C(I,2)=EXOG(I,80)                         00089400
C132      345 CONTINUE
        C     WHEAT PRODUCTION                                                    00089900
0133      350 YIELD(I+2,2) = C(I,6)                                               00090000
C134          IF(C(I,10).NE.0.0) GO TO 355                                        00090100
C135          C(I,10)=C(I,2)*C(I,6)                                               00090200
0136      355 CONTINUE                                                            00090300
0137          IF ((C(I,2)* C(I,6)).NE.C(I,10)) C(I,6)=C(I,10) / C(I,2)            00090400
        C     WHEAT SUPPLY                                                        00090500
C138          C(I,22)=C(I,10)+EXOG(I,4)+C(J,42) - C(J,151)                        00090600
        C     WHEAT TOTAL PRODUCTION EXPENSE                                      00091200
0139          C(I,18)=C(I,2)*C(I,14)                                              00091300
0140          IF (C(I,3).NE.0.0.AND.C(I,7).NE.0.0.AND. C(I,11).NE.0.0) C(I,7)     00091400
             1=C(I,11)/C(I,3)                                                     00091500
        C     SOYBEANS HARVESTED ACREAGE                                          00091600
C141          IF(C(I,3).NE.0.0) GO TO 360                                         00091700
```

```
0142             C(I,3)=(B(I,3)*(1.0+(E(14)*((C(J,27)-B(J,27))/B(J,27)))+(E(15)*((C00091800
                1(J,25)-B(J,25))/B(J,25)))+(E(16)*((C(J,26)-B(J,26))/B(J,26)))+(E(500091900
                23)*((C(J,28)-B(J,28))/B(J,28)))+(E(57)*EXOG(I,38))))+(1.0-ADJ(3))*00092000
                3(C(J,3)-B(J,3))                                                    00092100
0143        360 CONTINUE
         C       SOYBEANS PRODUCTION                                                00092600
0144        365 YIELD(I+2,3) = C(I,7)                                               00092700
0145             IF(C(I,11).NE.0.0) GO TO 370                                       00092800
0146             C(I,11)=C(I,3)*C(I,7)                                              00092900
0147        370 CONTINUE                                                            00093000
0148             IF ((C(I,3)*C(I,7)) .NE.C(I,11)) C(I,7)=C(I,11)/C(I,3)             00093100
         C       SOYBEAN SUPPLY                                                     00093200
0149             C(I,23)=C(I,11)+C(J,43) - C(J,156)                                 00093300
         C       SOYBEAN TOTAL PRODUCTION EXPENSES                                  00093900
0150             C(I,19)=C(I,3)*C(I,15)                                             00094000
0151             IF (C(I,4).NE.0.0 .AND. C(I,8).NE. 0.0 .AND. C(I,12).NE.0.0) C(I,800094100
                1)=(C(I,12)/C(I,4))*480.00D0                                        00094200
         C       COTTON HARVESTED ACREAGE                                           00094300
0152             IF(C(I,4).NE.0.0) GO TO 375                                        00094400
0153             C(I,4)=(B(I,4)*(1.0+(E(20)*((C(J,28)-B(J,28))/B(J,28)))+E(21)*((C(00094500
                1J,25)-B(J,25))/B(J,25)) +(E(22)*((C(J,27)-B(J,27))/B(J,27)))+(E(5400094600
                2)*((C(J,26)-B(J,26))/B(J,26)))+(E(58)*EXOG(I,38))))+(1.0-ADJ(4))*(00094700
                3C(J,4)-B(J,4))                                                     00094800
0154             IF (C(I,4).GT.EXOG(I,81)) WRITE(6,83)(TITLE(4,K),K=1,20),AY(I)    00094900
0155             IF (C(I,4).GT.EXOG(I,81)) C(I,4)=EXOG(I,81)                        00095000
0156        375 CONTINUE
         C       COTTON PRODUCTION                                                  00095500
0157        380 YIELD(I+2,4) =C(I,8)                                                00095600
0158             IF(C(I,12).NE.0.0) GO TO 385                                       00095700
0159             C(I,12)=(C(I,4)*C(I,8))/480.0D0                                    00095800
0160        385 CONTINUE                                                            00095900
0161             IF (((C(I,4)*C(I ,8))/480.0).NE.C(I,12))C(I,8)= (C(I,12)/C(I,4))* 00096000
                1480.0D0                                                            00096100
         C       COTTON SUPPLY                                                      00096200
0162             C(I,24)=C(I,12)+EXOG(I,7)+C(J,44) - C(J,152)                       00096300
         C       COTTON TOTAL PRODUCTION EXPENSES                                   00096900
0163             C(I,20)= C(I,4)*C(I,16)                                            00097000
         C-SWITCH THE T-1 PRICES OF WH,CAT,AND FG BACK TO ORIGINAL VALUES IF THEY00097100
         C ARE  STORED IN VARIABLES WHPRIC,COTPRC,FGPRC.                            00097200
0164             IF (FGPRIC .NE. 0.0) C(J,25) =FGPRIC                               00097300
0165             IF (WHPRIC .NE. 0.0) C(J,26) =WHPRIC                               00097400
0166             IF(SOYPRC.NE.0.0) C(J,27) = SOYPRC                                 00097500
0167             IF (COTPRC .NE. 0.0) C(J,28) =COTPRC                               00097600
0168             RETURN                                                             00097700
0169             END                                                                00097800
```

```
      SUBROUTINE WOLFE(IC,ID,N,EC,EP,ADJ,FAC,LIM)
C       QUADRATIC PROGRAM BY THE WOLFE METHOD
C       MINIMIZES OBJECTIVE FUNCTION (Z)
C       Z= P(J) * X(J) + X(I) * C(I,J) * X(J)
C       THE CONSTRAINTS ARE
C       A(I,J) * X(J) .LE. B(I)
C       ALL X(J) .GT. 0
C
      DIMENSION COST(26),T(10,26),PRFIT(26),TT(26),DIFF(26),RATIO(10)
      DIMENSION IB(10),III(25),OPP(10),EC(3),FAC(1)
      COMMON/WOLF/X(26)
      COMMON/DATA1/C(5,5),P(5)
      COMMON/DATA2/M,A(5,5),B(5)
  112 FORMAT (13X,'THE OBJECTIVE FUNCTION IS UNBOUNDED.')
      NREAD = 5
      NPRINT = 6
C
C
      CALL DATAN(IC,ID,EC,EP,N,ADJ)
      CALL CONST(N,ID,IC)
      ITMAX=50
  350 MP1=M+1
      MM1=M-1
      NP1=N+1
      NP2=N+2
      MN=M+N
      MNM1=MN-1
      MNP1=MN+1
      MNP2=MN+2
      NV=MN+N
      NVP1=NV+1
      NVP2=NV+2
      NY=NV+M
      NYP1=NY+1
      NYP2=NY+2
      NZ=NY+N
      NC=NZ+1
      NZP2=NZ+2
      DO 180 I=1,MN
      DO 180 J=1,NC
  180 T(I,J)=0.0
      DO 182 I=1,M
  182 T(I,1)=B(I)
      DO 183 I=MP1,MN
      J=I-M
  183 T(I,1)=-P(J)
      DO 184 I=1,M
      DO 184 J=1,N
      JP1=J+1
  184 T(I,JP1)=A(I,J)
      DO 185 I=1,N
      DO 185 J=1,N
      IPM=I+M
      JP1=J+1
  185 T(IPM,JP1)=2.*C(I,J)
      DO 186 I=MP1,MN
      IMM=I-M
      DO 186 J=NP2,MNP1
```

```
      JMN=J-N-1
  186 T(I,J)=A(JMN,IMM)
      DO 187 I=1,MN
      IJ=I + NVP1
      DO 187 J=NYP2,NC
      IF(J-IJ) 187,179,187
  179 T(I,J)=1.0
  187 CONTINUE
      DO 188 I=MP1,MN
      IJ=I-M+MNP1
      DO 188 J=MNP2,NC
      IF(J-IJ) 188,178,188
  178 T(I,J)=-1.0
  188 CONTINUE
      DO 208 I=1,MN
      OPP(I)=T(I,1)
  208 CONTINUE
      DO 340 J=1,NZ
  340 COST(J)=0.0
      DO 189 I=1,M
      J=NP1+I
  189 COST(J)=T(I,1)
      DO 190 J=NYP2,NC
  190 COST(J)=9999.0
      NN=NZ-MN
      DO 25 KK=1,NZ
   25 III(KK)=KK
      DO 1 I=1,MN
    1 IB(I)=NN+I
      K=0
C
C*******************************ITERATION STARTS*************************
C
   19 K=K+1
      DO 2 J=1,NC
    2 PRFIT(J)=0.0
      DO 3 J=1,NC
      SUM=0.0
      DO 4 I=1,MN
      JJ=IB(I)+1
    4 SUM=SUM+COST(JJ)*T(I,J)
      PRFIT(J)=SUM
    3 DIFF(J)=COST(J)-PRFIT(J)
C
C**************************FIND THE PIVOT ELEMENT--T(IPR,IPC)***********
C
  666 IPC=0
      TEST=0.0
C                FIND THE VARIABLE WITH THE LARGEST PROFIT
      DO 5 I=2,NC
  235 IF(DIFF(I)-TEST) 6,5,5
    6 TEST=DIFF(I)
      IPC=I
    5 CONTINUE
      IF(IPC)99,99,7
    7 KCK=0
      DO 8 I=1,MN
      IF(T(I,IPC))32,32,20
```

```
   20 RATIO(I)=T(I,1)/T(I,IPC)
      GO TO 8
   32 KCK=KCK+1
      IF(KCK-MN)21,31,21
   21 RATIO(I)=1.E20
    8 CONTINUE
C                     REMOVE LIMITING VARIABLE
      DO 9 I=1,MN
      IF(RATIO(I))9,10,10
   10 IF(RATIO(I).GT.10000.)RATIO(I)=10000.
      TEST=RATIO(I)
      IPR=I
      GO TO 11
    9 CONTINUE
   11 DO 12 I=1,MN
      IF(TEST-RATIO(I))12,12,13
   13 TEST=RATIO(I)
      IPR=I
   12 CONTINUE
C             START PIVOTING AND INTRODUCE NEW VARIABLE INTO SOLUTION
      PIVOT=T(IPR,IPC)
      DO 15 J=1,NC
   15 T(IPR,J)=T(IPR,J)/PIVOT
      DO 171 I=1,MN
      IF(I-IPR)17,171,17
   17 DO 18 J=1,NC
   18 TT(J)=T(IPR,J)*T(I,IPC)/T(IPR,IPC)
      DO 172 J=1,NC
  172 T(I,J)=T(I,J)-TT(J)
  171 CONTINUE
      COST(IPR)=COST(IPC)
      IB(IPR)=IPC-1
C                         RECOMPUTE COSTS
  205 DO 176 J=1,NYP1
  176 COST(J)=0.0
      DO 197 I=1,MN
      IF(IB(I)-MN)192,192,195
  192 JJ=IB(I)+MNP1
      GO TO 198
  195 IF(IB(I)-NY)196,196,197
  196 JJ=IB(I)-MNM1
      GO TO 198
  198 COST(JJ)=T(I,1)
  197 CONTINUE
   99 SUM=0.0
      DO 201 I=1,MN
      IN=IB(I)
      IF(IN.GT.N) GO TO 201
      SUM=SUM+P(IN)*T(I,1)
  201 CONTINUE
      FRST=SUM
      SUM=0.0
      DO 202 I=1,MN
      DO 202 J=1,MN
      IN=IB(I)
      IF(IN.GT.N)GO TO 202
      JN=IB(J)
      IF(JN.GT.N) GO TO 202
```

```
              SUM=SUM+C(IN,JN)*T(I,1)*T(J,1)
          202 CONTINUE
              SCND=SUM
              OBJ=FRST+SCND
              IF(IPC)317,317,318
          318 IF(K-ITMAX)19,830,830
          317 CONTINUE
              DO 28 I=1,MN
          219 NUM=IB(I)
              X(NUM)=T(I,1)
           28 CONTINUE
              GO TO 30
           31 WRITE(NPRINT,112)
              GO TO 30
          830 WRITE(NPRINT,831)IC,ID
          831 FORMAT(1X,'ITERATION LIMIT EXCEEDED',2I5)
              GO TO 317
           30 IF(IC.EQ.0) GO TO 61
              GO TO (71,72,73,74,75,76,77),IC
           71 FAC(1)=0.002*X(3)
              GO TO 61
           72 FAC(2)=0.0007*X(5)
              GO TO 61
           73 FAC(3)=0.007*X(5)
              GO TO 61
           74 FAC(4)=0.0035*X(5)
              GO TO 61
           75 FAC(5)=0.0024*X(4)
              GO TO 61
           76 FAC(6)=0.002*X(3)
              GO TO 61
           77 FAC(7)=0.002*X(3)
           61 RETURN
              END
```

```
      SUBROUTINE CONST(N,ID,IC)
      COMMON/DATA2/M,A(5,5),B(5)
      DIMENSION EC(1)
      DO 8 L=1,5
      DO 8 M=1,5
    8 A(L,M)=0.
C        ENERGY CONSTRAINTS BY TYPE OF ENERGY
      M=3
      READ(5,10)(B(LL),LL=1,3)
   10 FORMAT(7F10.0)
      GO TO (1,2,3,4,5,6,7),IC
    1 A(1,1)=0.013
      A(1,2)=0.132
      A(1,3)=0.78
      A(2,1)=0.017
      A(2,2)=0.038
      A(2,3)=0.07
      A(3,1)=0.60
      A(3,2)=0.51
      A(3,3)=21.33
      GO TO 100
    2 A(1,1)=0.01
      A(1,2)=0.132
      A(1,3)=0.42
      A(1,4)=0.132
      A(1,5)=0.78
      A(2,1)=0.003
      A(2,2)=0.038
      A(2,4)=0.038
      A(2,5)=0.07
      A(3,1)=0.88
      A(3,2)=0.51
      A(3,4)=0.51
      A(3,5)=21.33
      GO TO 100
    3 A(1,1)=0.012
      A(1,2)=0.132
      A(1,3)=0.84
      A(1,4)=0.132
      A(1,5)=0.78
      A(2,1)=0.016
      A(2,2)=0.038
      A(2,4)=0.038
      A(2,5)=0.07
      A(3,1)=0.63
      A(3,2)=0.51
      A(3,4)=0.51
      A(3,5)=21.33
      GO TO 100
    4 A(1,1)=0.012
      A(1,2)=0.132
      A(1,3)=0.32
      A(1,4)=0.132
      A(1,5)=0.78
      A(2,1)=0.015
      A(2,2)=0.038
      A(2,4)=0.038
      A(2,5)=0.07
```

```
      A(3,1)=0.64
      A(3,2)=0.51
      A(3,4)=0.51
      A(3,5)=21.33
      GO TO 100
    5 A(1,1)=0.012
      A(1,2)=0.132
      A(1,3)=0.32
      A(1,4)=0.78
      A(2,1)=0.02
      A(2,2)=0.038
      A(2,4)=0.07
      A(3,1)=0.51
      A(3,2)=0.51
      A(3,4)=21.33
      GO TO 100
    6 A(1,1)=0.008
      A(1,2)=0.132
      A(1,3)=0.078
      A(2,1)=0.008
      A(2,2)=0.038
      A(2,3)=0.07
      A(3,1)=0.76
      A(3,2)=0.51
      A(3,3)=21.33
      GO TO 100
    7 A(1,1)=0.013
      A(1,2)=0.132
      A(1,3)=0.78
      A(2,1)=0.015
      A(2,2)=0.038
      A(2,3)=0.07
      A(3,1)=0.68
      A(3,2)=0.51
      A(3,3)=21.33
  100 RETURN
      END
```

```
      SUBROUTINE DATAN(IC,ID,EC,EP,N,ADJ)
      COMMON/DATA1/C(5,5),P(5)
      DIMENSION EC(1)
      DO 10 J=1,5
      P(J)=0.
      DO 10 K=1,5
      C(J,K)=0.
   10 CONTINUE
      GO TO (1,2,3,4,5,6,7),IC
    1 C(1,1)=0.0022*EP
      C(2,2)=4.75*EP
      N=2
      P(1)=-C.32*EP+(0.075*ACJ+0.013*EC(1)+0.017*EC(2)+0.075*EC(3))
      P(2)=-5.86*EP+(3.08*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3))
      IF(ID)100,100,11
   11 N=3
      C(3,3)=C.010*EP
      C(3,1)=-0.002*EP
      C(3,1)=0.5*C(3,1)
      C(1,3)=C(3,1)
      P(3)=-0.75*EP+0.33*ADJ+0.78*EC(1)+0.07*EC(2)+21.33*EC(3)
      IF(P(3))100,12,12
   12 N=2
      GO TO 100
    2 C(1,1)=0.00691*EP
      C(2,2)=0.75*EP
      C(3,3)=0.61*EP
      C(4,4)=140.0*EP
      C(3,2)=0.55*EP
      C(3,2)=0.5*C(3,2)
      C(2,3)=C(3,2)
      P(1)=-0.50*EP+0.094*ADJ+0.01*EC(1)+0.003*EC(2)+0.88*EC(3)
      P(2)=-2.90*EP+3.08*ADJ+0.13*EC(1)+0.038*EC(2)+0.51*EC(3)
      P(3)=-3.95*EP+0.92*ADJ+0.42*EC(1)
      P(4)=-51.0*EP+(7.32*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3))
      N=4
      IF(ID)100,100,21
   21 N=N+1
      C(5,5)=0.0113*EP
      C(5,1)=-0.00028*EP
      C(5,1)=0.5*C(5,1)
      C(1,5)=C(5,1)
      P(5)=-0.74*EP+0.33*ADJ+0.78*EC(1)+0.07*EC(2)+21.33*EC(3)
      IF(P(5))1C0,22,22
   22 N=4
      GO TO 100
    3 C(1,1)=0.0153*EP
      C(2,2)=28.7*EP
      C(3,3)=29.65*EP
      C(4,4)=2.51*EP
      C(3,2)=9.2*EP
      C(3,2)=0.5*C(3,2)
      C(2,3)=C(3,2)
      P(1)=-4.7*EP+0.68*ADJ+0.012*EC(1)+0.016*EC(2)+0.63*EC(3)
      P(2)=-115.4*EP+(3.08*ACJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3))
      P(3)=-26C.C*EP+1.26*ADJ+0.84*EC(1)
      P(4)=-51.0*EP+(7.32*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3))
      N=4
```

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FORTRAN IV G LEVEL  21                 CATAN               DATE = 75209            10/40/14

            IF(ID)100,100,31
         31 N=5
            C(5,5)=0.302*EP
            C(5,1)=-0.017*EP
            C(5,1)=0.5*C(5,1)
            C(1,5)=C(5,1)
            P(5)=-16.49*EP+(0.42*ADJ+0.78*EC(1)+0.07*EC(2)+21.33*EC(3))
            GO TO 100
          4 C(1,1)=0.00065*EP
            C(2,2)=2.75*EP
            C(3,3)=2.42*EP
            C(4,4)=29.6*EP
            C(3,2)=2.02*EP
            C(3,2)=0.5*C(3,2)
            C(2,3)=C(3,2)
            P(1)=-0.33*EP+(0.068*ADJ+0.012*EC(1)+0.015*EC(2)+0.64*EC(3))
            P(2)=-11.6*EP+3.08*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3)
            P(3)=-13.1*EP+0.98*ADJ+0.32*EC(1)
            P(4)=-48.9*EP+(7.32*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3))
            N=4
            IF(ID)100,100,41
         41 N=5
            C(5,5)=0.11*EP
            C(5,1)=-0.0007*EP
            C(5,1)=0.5*C(5,1)
            C(1,5)=C(5,1)
            P(5)=-4.9*EP+(0.33*ADJ+0.78*EC(1)+0.07*EC(2)+21.33*EC(3))
            GO TO 100
          5 C(1,1)=0.0021*EP
            C(2,2)=1.51*EP
            C(3,3)=1.21*EP
            C(2,3)=1.01*EP
            C(2,3)=0.5*C(2,3)
            C(3,2)=C(2,3)
            N=3
            P(1)=-0.55*EP+(0.048*ADJ+0.012*EC(1)+0.02*EC(2)+0.51*EC(3))
            P(2)=-5.8*EP+3.08*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3)
            P(3)=-6.5*EP+(1.11*ADJ+0.32*EC(1))
            IF(ID)100,100,51
         51 N=4
            C(4,4)=0.07*EP
            C(4,1)=-0.0012*EP
            C(4,1)=0.5*C(4,1)
            C(1,4)=C(4,1)
            P(4)=-3.3*EP+(0.33*ADJ+0.78*EC(1)+0.07*EC(2)+21.33*EC(3))
            GO TO 100
          6 C(1,1)=0.00341*EP
            C(2,2)=7.2*EP
            N=2
            P(1)=-0.43*EP+(0.078*ADJ+0.008*EC(1)+0.008*EC(2)+0.76*EC(3))
            P(2)=-10.5*EP+3.08*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3)
            IF(ID)100,100,61
         61 N=3
            C(3,3)=0.014*EP
            C(3,1)=-0.0016*EP
            C(3,1)=0.5*C(3,1)
            C(1,3)=C(3,1)
            P(3)=-2.1*EP+0.28*ADJ+0.78*EC(1)+0.07*EC(2)+21.33*EC(3)
```

FORTRAN IV G LEVEL 21 DATAN DATE = 75209 10/40/14

```
      IF(P(3))100,62,62
   62 N=2
      GO TO 100
    7 C(1,1)=0.0025*EP
      C(2,2)=9.8*EP
      N=2
      P(1)=-0.24*EP+0.097*ADJ+0.013*EC(1)+0.015*EC(2)+0.68*EC(3)
      P(2)=-12.1*EP+(3.08*ADJ+0.132*EC(1)+0.038*EC(2)+0.51*EC(3))
      IF(ID)100,100,71
   71 N=3
      C(3,3)=0.0098*EP
      C(3,1)=-0.0024*EP
      C(3,1)=0.5*C(3,1)
      C(1,3)=C(3,1)
      P(3)=-1.11*EP+0.28*ADJ+0.78*EC(1)+0.07*EC(2)+21.33*EC(3)
      IF(P(3))100,72,72
   72 N=2
  100 RETURN
      END
```

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FORTRAN IV G LEVEL  21                STAT              DATE = 75209          10/40/14

0001            SUBROUTINE STAT(X,YIELD,ENERGY,XCOST,IC,EC,ADJ,EP)
0002            DIMENSION X(1),ENERGY(1),EC(1)
0003            GO TO (1,2,3,4,5,6,7),IC
0004          1 YIELD=19.82+0.32*X(1)-.0022*X(1)**2+5.86*X(2)-4.75*X(2)**2+0.75*X(
               13)-0.010*X(3)**2+0.002*X(1)*X(3)
0005            ENERGY(1)=9.898+0.013*X(1)+0.132*X(2)+0.78*X(3)
0006            ENERGY(2)=0.029+0.017*X(1)+0.038*X(2)+0.07*X(3)
0007            ENERGY(3)=1.10+0.6*X(1)+0.51*X(2)+21.33*X(3)
0008            XCOST=ENERGY(1)*EC(1)+ENERGY(2)*EC(2)+ENERGY(3)*EC(3)+(12.96+0.075
               1*X(1)+3.08*X(2)+0.33*X(3))*ADJ+1.05*1.1*EP
0009            X(5)=X(3)
0010            X(3)=1.68
0011            X(4)=0.
0012            GO TO 100
0013          2 YIELD=7.080+0.50*X(1)-0.00691*X(1)**2+0.74*X(5)-0.0113*X(5)**2+.00
               1028*X(1)*X(5)+3.95*X(3)+2.90*X(2)-0.610*X(3)**2-0.750*X(2)**2-0.55
               2*X(2)*X(3)+51.0*X(4)-140.0*X(4)**2
0014            ENERGY(1)=10.87+0.01*X(1)+0.132*X(2)+0.42*X(3)+0.132*X(4)+.78*X(5)
0015            ENERGY(2)=0.004+0.003*X(1)+0.023*X(2)+0.038*X(4)+0.07*X(5)
0016            ENERGY(3)=1.13+0.88*X(1)+0.51*X(2)+0.51*X(4)+21.33*X(5)
0017            XCOST=ENERGY(1)*EC(1)+ENERGY(2)*EC(2)+ENERGY(3)*EC(3)+(7.46+0.094*
               1X(1)+3.08*X(2)+0.92*X(3)+3.08*X(4)+0.33*X(5))*ADJ+1.05*EP
0018            GO TO 100
0019          3 YIELD=-709.5+4.7*X(1)-0.0153*X(1)**2+16.49*X(5)-0.302*X(5)**2+0.01
               17*X(1)*X(5)+260.1*X(3)+115.4*X(2)-29.65*X(3)**2-28.7*X(2)**2-9.2*X
               2(2)*X(3)+34.8*X(4)-2.51*X(4)**2
0020            ENERGY(1)=22.41+0.012*X(1)+0.132*X(2)+0.84*X(3)+0.132*X(4)+0.78*X(
               15)
0021            ENERGY(2)=0.98+0.016*X(1)+0.038*X(2)+0.038*X(4)+0.07*X(5)
0022            ENERGY(3)=6.16+0.63*X(1)+0.52*X(2)+0.52*X(4)+21.33*X(5)
0023            XCOST=ENERGY(1)*EC(1)+ENERGY(2)*EC(2)+ENERGY(3)*EC(3)+(61.65+0.068
               1*X(1)+3.08*X(2)+1.26*X(3)+3.08*X(4)+0.42*X(5))*ADJ+1.05*6.0*EP
0024            IF(X(5).EQ.0.) YIELD=YIELD+148
0025            GO TO 100
0026          4 YIELD=-12.1+0.33*X(1)-0.00065*X(1)**2+4.9*X(5)-.11*X(5)**2+0.0007*
               1X(1)*X(5)+13.1*X(3)+11.6*X(2)-2.4*X(3)**2-2.75*X(2)**2-2.0*X(2)*X(
               23)+48.9*X(4)-29.6*X(4)**2
0027            ENERGY(1)=14.945+0.012*X(1)+0.132*X(2)+0.32*X(3)+0.132*X(4)+0.78*X
               1(5)
0028            ENERGY(2)=0.78+0.015*X(1)+0.038*X(2)+0.038*X(4)+0.07*X(5)
0029            ENERGY(3)=15.32+0.64*X(1)+0.51*X(2)+0.51*X(4)+21.33*X(5)
0030            XCOST=ENERGY(1)*EC(1)+ENERGY(2)*EC(2)+ENERGY(3)*EC(3)+(10.964+0.06
               18*X(1)+3.08*X(2)+0.98*X(3)+3.08*X(4)+0.33*X(5))*ADJ+1.05*1.9*EP
0031            IF(X(5).EQ.0) YIELD=YIELD+31.7
0032            GO TO 100
0033          5 YIELD=-12.05+0.55*X(1)-0.00214*X(1)**2+3.3*X(4)-0.070*X(4)**2+0.00
               112*X(1)*X(4)+5.8*X(2)+6.5*X(3)-1.51*X(2)**2-1.21*X(3)**2-1.01*X(2)
               2*X(3)
0034            ENERGY(1)=10.33+0.012*X(1)+0.132*X(2)+0.32*X(3)+0.78*X(4)
0035            ENERGY(2)=0.412+0.02*X(1)+0.038*X(2)+0.07*X(4)
0036            ENERGY(3)=7.52+0.51*X(1)+0.51*X(2)+21.33*X(4)
0037            XCOST=ENERGY(1)*EC(1)+ENERGY(2)*EC(2)+ENERGY(3)*EC(3)+(9.382+0.048
               1*X(1)+3.8*X(2)+1.11*X(3)+0.32*X(4))*ADJ+1.5*1.0*EP
0038            IF(X(4).EQ.0.) YIELD=YIELD+24.
0039            X(5)=X(4)
0040            X(4)=0.
0041            GO TO 100
0042          6 YIELD=28.0+0.43*X(1)-0.00341*X(1)**2+2.1*X(3)-0.014*X(3)**2+0.0016
```

```
                  1*X(1)*X(3)+10.5*X(2)-7.2*X(2)**2
0043               ENERGY(1)=9.190+0.008*X(1)+0.132*X(2)+0.78*X(3)
0044               ENERGY(2)=0.024+0.008*X(1)+0.038*X(2)+0.07*X(3)
0045               ENERGY(3)=2.16+0.76*X(1)+0.51*X(2)+21.33*X(3)
0046               XCOST=ENERGY(1)*EC(1)+ENERGY(2)*EC(2)+ENERGY(3)*EC(3)+(9.358+0.078
                  1*X(1)+3.08*X(2)+0.28*X(3))*ADJ+1.05*2.4*EP
0047               IF(X(3).EQ.0.)YIELD=YIELD+11.0
0048               X(5)=X(3)
0049               X(3)=1.95
0050               X(4)=0.
0051               GO TO 100
0052             7 YIELD=28.8+0.24*X(1)-0.00250*X(1)**2+1.11*X(3)-0.0098*X(3)**2+.002
                  14*X(1)*X(3)+12.1*X(2)-9.8*X(2)**2
0053               ENERGY(1)=11.07+0.013*X(1)+0.132*X(2)+0.78*X(3)
0054               ENERGY(2)=0.012+0.015*X(1)+0.038*X(2)+0.07*X(3)
0055               ENERGY(3)=1.2+0.68*X(1)+0.51*X(2)+21.33*X(3)
0056               XCOST=ENERGY(1)*EC(1)+ENERGY(2)*EC(2)+ENERGY(3)*EC(3)+(11.275+0.09
                  17*X(1)+3.08*X(2)+0.28*X(3))*ADJ+1.05*1.6*EP
0057               IF(X(3).EQ.0.) YIELD=YIELD+3.5
0058               X(5)=X(3)
0059               X(3)=1.99
0060               X(4)=0.
0061           100 RETURN
0062               END
```

07/28/75

SIMULATION NAME	IDENTIFICATION NO.
10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES	1

SIMULATE 5 YEARS, BEGINNING IN 1975

BASELINE PROJECTIONS USED IN THIS SIMULATION WERE DEVELOPED MARCH 1975

FARM PROGRAM FOR THIS SIMULATION USED THE FOLLOWING POLICY VARIABLES:

TARGET PRICES

TARGET PRICES ADJUSTED BEGINNING IN YEAR 1975.

LOAN RATES WILL BE USED TO SUPPORT MARKET PRICES AS NEEDED.

ELASTICITY INFORMATION

THE DEFAULT ELASTICITIES WILL BE USED

THE CED LIVESTOCK PRICE FLEXIBILITY MATRIX WILL BE USED.

THE USER SUPPLIED 1 EXOGENOUS DATA CARDS, THESE ARE:

VARIABLE NAME	CROP CODE	FIRST YEAR	NO. YEARS	CONSECUTIVE OBSERVATIONS					
A FILE OF ZEROS	108	1973	6	563.000	664.000	725.000	755.000	776.000	817.000

YEAR: 1975

PETROLEUM PRICE $ 0.406/GALLON

NATURAL GAS PRICE $ 0.746/MCF

ELECTRICITY PRICE $ 0.027/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	34.05	37.56	11.96	1.29	72.27	67.07	0.52	1.68	0.0	26.81	0.05
SOYBEANS	27.67	32.14	12.74	0.15	38.38	34.48	0.47	2.85	0.18	21.00	0.01
COTTON	478.53	139.83	30.88	2.85	147.56	83.61	1.18	4.12	5.55	23.89	0.17
CORN	104.70	67.33	19.71	4.36	191.71	227.22	1.12	2.16	0.78	20.05	0.07
SORGHUM	58.35	40.84	13.36	2.99	91.75	123.82	0.77	2.16	0.0	20.10	0.05
OATS	56.26	28.97	10.04	0.49	51.31	51.30	0.56	1.95	0.0	15.22	0.03
BARLEY	41.78	32.22	11.91	0.62	34.72	37.77	0.55	1.99	0.0	13.31	0.03
FEED GRAIN	84.46	54.30	16.58	3.21	140.70	167.18	0.93	2.11	0.48	18.64	

YEAR: 1976

PETROLEUM PRICE $ 0.446/GALLON

NATURAL GAS PRICE $ 0.821/MCF

ELECTRICITY PRICE $ 0.030/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	33.02	35.40	10.99	1.10	44.54	60.91	0.43	1.68	0.0	12.50	0.03
SOYBEANS	27.28	29.97	12.59	0.13	34.30	33.16	0.14	2.87	0.17	16.02	0.01
COTTON	468.69	149.67	30.69	2.78	142.18	80.25	1.17	4.12	5.35	23.45	0.16
CORN	102.68	64.09	19.27	3.95	172.19	200.94	0.89	2.17	0.73	19.17	0.07
SORGHUM	57.01	38.27	13.20	2.80	87.58	115.35	0.28	2.12	0.0	20.30	0.05
OATS	53.97	26.44	9.90	0.38	41.35	38.61	0.37	1.95	0.0	15.05	0.03
BARLEY	40.63	29.62	11.73	0.44	26.18	25.85	0.47	1.99	0.0	12.95	0.03
FEED GRAIN	82.59	51.32	16.25	2.90	125.91	146.93	0.69	2.11	0.45	18.08	

YEAR: 1977

PETROLEUM PRICE $ 0.497/GALLON

NATURAL GAS PRICE $ 0.903/MCF

ELECTRICITY PRICE $ 0.032/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	33.26	39.47	11.17	1.14	49.73	62.35	0.45	1.68	0.0	16.05	0.03
SOYBEANS	27.09	31.33	12.52	0.12	32.61	32.70	0.03	2.87	0.17	13.20	0.01
COTTON	465.22	161.59	30.62	2.76	139.96	79.13	1.17	4.12	5.28	23.23	0.16
CORN	102.17	68.42	19.18	3.87	168.43	196.24	0.86	2.17	0.73	18.91	0.07
SORGHUM	56.68	40.80	13.17	2.77	86.86	113.84	0.20	2.12	0.0	20.34	0.05
OATS	53.00	27.63	9.67	0.34	33.77	36.30	0.34	1.95	0.0	9.50	0.02
BARLEY	40.15	31.16	11.52	0.39	19.88	23.69	0.46	1.99	0.0	7.40	0.01
FEED GRAIN	82.04	54.65	16.13	2.84	121.77	143.29	0.65	2.11	0.44	16.55	

YEAR: 1978

PETROLEUM PRICE $ 0.540/GALLON

NATURAL GAS PRICE $ 0.993/MCF

ELECTRICITY PRICE $ 0.036/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	32.97	41.44	10.94	1.10	43.24	60.71	0.42	1.68	0.0	11.36	0.02
SOYBEANS	27.11	34.04	12.53	0.12	32.68	32.74	0.04	2.87	0.17	13.28	0.01
COTTON	503.12	183.14	31.32	3.05	160.45	93.22	1.20	4.13	6.16	24.79	0.17
CORN	102.40	74.75	19.22	3.90	17[illegible].02	198.24	0.87	2.17	0.73	19.02	0.07
SORGHUM	56.84	44.63	13.19	2.78	87.14	114.42	0.24	2.12	0.0	20.32	0.05
OATS	53.38	30.38	9.74	0.35	36.35	37.27	0.35	1.95	0.0	11.54	0.02
BARLEY	40.32	34.13	11.58	0.41	21.72	24.59	0.47	1.99	0.0	9.13	0.02
FEED GRAIN	82.28	59.75	16.18	2.86	123.34	144.83	0.67	2.11	0.44	17.08	

THE MARKET PRICE OF 28 IN 1978WAS $ 0.400
CROP NO. 28 IN YEAR 1978 NEW PRICE IS, 0.41 STOCKS BOUGHT ARE, 0.19

YEAR: 1979

PETROLEUM PRICE $ 0.594/GALLON

NATURAL GAS PRICE $ 1.092/MCF

ELECTRICITY PRICE $ 0.039/KWH

CROP	YIELD	VAR COST	PETROL	NAT GAS	ELECT	FERT	HERB	CULT	PEST	IRRIG	PCT IRR
WHEAT	32.83	44.34	10.85	1.07	40.56	59.92	0.41	1.68	0.0	8.80	0.02
SOYBEANS	27.26	38.14	12.57	0.12	33.90	33.11	0.13	2.87	0.17	15.25	0.01
COTTON	394.39	176.77	29.61	2.33	110.64	59.16	1.12	4.10	4.04	20.79	0.15
CORN	102.21	80.62	19.18	3.88	168.49	196.48	0.86	2.17	0.73	18.88	0.07
SORGHUM	56.72	48.15	13.18	2.77	86.87	113.86	0.22	2.12	0.0	20.34	0.05
OATS	53.02	32.48	9.65	0.34	33.34	36.45	0.34	1.95	0.0	8.80	0.02
BARLEY	40.16	36.61	11.51	0.39	19.64	23.84	0.46	1.99	0.0	6.84	0.01
FEED GRAIN	82.08	64.39	16.13	2.84	121.72	143.48	0.65	2.11	0.44	16.37	

10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES

FEED GRAINS

YEAR	HARVESTED ACREAGE M. AC.	YIELD PER ACRE T./AC.	TOTAL PRODUCTION M. T.	VARIABLE EXPENSE PER ACRE $/AC.	TOTAL SUPPLY M. T.	CORN PRICE RECEIVED $/BU.	FEED DEMAND M. T.	DOMESTIC DEMAND M. T.	TOTAL EXPORTS M. T.	TOTAL DISAPPEAR-ANCE M. T.	ENDING YEAR STOCK M. T.	CASH RECEIPTS M. $
1973	102.34	2.00	205.04	36.20	237.70	2.55	153.60	171.10	44.40	215.10	22.20	9982.26
1974	100.70	1.64	165.10	52.94	187.20	3.10	123.30	136.20	37.20	173.40	14.40	12336.00
1975	102.60	2.25	230.51	54.30	245.41	1.89	141.54	162.27	45.61	207.87	37.54	10369.52
1976	103.09	2.20	226.49	51.32	264.33	1.87	155.35	177.51	49.83	227.34	36.99	9975.93
1977	103.65	2.18	226.21	54.65	263.50	2.11	156.74	179.64	48.81	228.45	35.05	10931.61
1978	105.07	2.19	229.96	59.75	265.32	2.22	156.64	180.19	48.18	228.37	36.94	11580.72
1979	107.31	2.18	234.28	64.39	271.52	2.32	141.70	183.88	49.26	233.13	38.39	12483.58
% CHANGE CALCULATED FROM BASE FOR 1979												
	1.23	-6.46	-5.30	-23.05	-8.11	22.31	-3.42	-2.66	-14.63	-5.46	-21.49	15.83
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979												
	-0.01	-2.00	-2.06	-21.95	-2.68	5.15	-0.44	-0.37	-4.10	-1.20	-10.80	3.16

WHEAT

YEAR	HARVESTED ACREAGE M. AC.	YIELD PER ACRE BU./AC.	TOTAL PRODUCTION M. BU.	VARIABLE EXPENSE PER ACRE $/AC.	TOTAL SUPPLY M. BU.	PRICE RECEIVED $/BU.	FEED DEMAND M. BU.	DOMESTIC DEMAND M. BU.	TOTAL EXPORTS M. BU.	TOTAL DISAPPEAR-ANCE M. BU.	ENDING YEAR STOCK M. BU.	CASH RECEIPTS M. $
1973	53.87	31.77	1711.40	20.13	2153.65	4.00	140.30	757.20	1147.90	1905.10	247.00	5688.11
1974	65.50	27.37	1793.00	32.13	2042.00	4.10	75.00	692.00	1100.00	1792.00	250.00	7264.00
1975	67.50	34.05	2298.15	37.56	2549.15	2.34	200.01	829.65	1269.23	2098.88	450.26	5167.63
1976	64.16	33.02	2118.24	35.40	2569.50	2.86	225.14	845.79	1223.71	2069.50	500.00	5619.23
1977	63.41	33.26	2109.11	39.47	2610.12	2.71	237.94	850.76	1181.34	2032.10	578.02	5488.02
1978	62.02	32.97	2044.59	41.44	2623.61	2.77	248.43	857.63	1168.84	2026.47	597.14	5429.95
1979	62.18	32.83	2041.12	44.34	2639.26	2.82	258.07	864.89	1167.46	2032.35	606.91	5517.13
% CHANGE CALCULATED FROM BASE FOR 1979												
	0.45	-5.93	-5.50	-11.36	-6.11	12.62	-0.74	-1.38	-8.43	-5.56	-7.91	6.43
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979												
	-0.38	-0.82	-1.05	-9.14	-2.25	0.72	0.39	0.09	-1.06	-0.59	-8.03	-0.59

SOYBEANS

YEAR	HARVESTED ACREAGE M. AC.	YIELD PER ACRE BU./AC.	TOTAL PRODUCTION M. BU.	VARIABLE EXPENSE PER ACRE $/AC.	TOTAL SUPPLY M. BU.	PRICE RECEIVED $/BU.	CRUSHINGS M. BU.	DOMESTIC DEMAND M. BU.	TOTAL EXPORTS M. BU.	TOTAL DISAPPEAR-ANCE M. BU.	ENDING YEAR STOCK M. BU.	CASH RECEIPTS M. $
1973	56.42	27.77	1566.52	27.52	1626.10	5.75	821.30	912.50	542.00	1436.00	171.60	8846.54
1974	52.50	23.49	1233.00	33.88	1404.00	6.25	725.00	804.00	465.00	1269.00	135.00	9919.00
1975	55.50	27.67	1535.43	32.14	1670.43	3.85	786.75	866.75	514.08	1380.84	289.59	5758.03
1976	55.92	27.28	1525.30	29.97	1814.89	3.60	880.09	960.09	578.96	1539.05	275.83	5385.73
1977	54.55	27.09	1477.94	31.33	1753.78	3.95	896.40	976.40	591.44	1567.85	185.93	5720.52
1978	53.55	27.11	1451.72	34.04	1637.64	4.80	892.20	972.20	574.71	1546.91	90.73	6824.46
1979	56.22	27.26	1532.50	38.14	1623.23	6.09	887.91	967.91	569.76	1537.67	85.57	9144.14
% CHANGE CALCULATED FROM BASE FOR 1979												
	-1.38	-3.48	-4.81	-20.54	-5.35	10.70	-5.54	-5.11	-8.84	-6.52	22.24	5.37
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979												
	0.08	-1.16	-1.08	-21.54	-1.28	3.32	-0.95	-0.87	-1.94	-1.27	-1.31	1.78

10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES

COTTON

YEAR	HARVESTED ACREAGE M. AC.	YIELD PER ACRE LBS./AC.	TOTAL PRODUCTION M. BALES	VARIABLE EXPENSE PER ACRE $/AC.	TOTAL SUPPLY M. BALES	PRICE RECEIVED $/LB.	MILL CONSUMP-TION M. BALES	DOMESTIC DEMAND M. BALES	TOTAL EXPORTS M. BALES	TOTAL DISAPPEAR-ANCE M. BALES	ENDING YEAR STOCK M. BALES	CASH RECEIPTS M. $
1973	11.90	528.40	13.10	118.51	17.08	0.44	7.40	7.40	6.10	13.50	3.80	2286.86
1974	12.60	441.90	11.60	145.39	15.40	0.40	5.70	5.70	3.50	9.20	6.20	2932.00
1975	9.40	478.53	9.37	139.83	15.57	0.41	6.16	6.16	3.88	10.04	5.53	1860.07
1976	9.88	468.69	9.65	149.67	15.18	0.44	6.43	6.43	3.81	10.24	4.94	2040.89
1977	10.09	465.22	9.78	161.59	14.72	0.58	6.41	6.41	4.80	11.21	3.51	2727.29
1978	12.27	503.12	12.87	183.14	16.38	0.41	6.00	6.00	4.63	10.63	5.75	2531.94
1979	9.72	394.39	7.98	176.77	13.73	0.64	6.12	6.12	4.16	10.28	3.45	2460.66
% CHANGE CALCULATED FROM BASE FOR 1979												
	-1.84	-21.78	-23.22	-17.68	-11.39	28.40	-2.88	-2.88	-13.28	-7.38	-21.52	-1.42
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979												
	2.73	-7.51	-4.52	-13.89	-2.97	8.13	-1.21	-1.21	-4.57	-2.60	-3.80	1.19

LIVESTOCK PRODUCTION

YEAR	BEEF AND VEAL M. LBS. CAR. WT.	PORK M. LBS. CAR. WT.	SHEEP AND LAMB M. LBS. CAR. WT.	CHICKEN M. LBS. RTC	TURKEY M. LBS. RTC	EGG M. DOZ.	MILK M. LBS.
1973	21634.00	12751.00	514.00	8916.00	1956.00	5544.00	115620.00
1974	23488.00	13688.00	470.00	8970.00	1945.00	5454.00	115400.00
1975	25300.00	11800.00	420.00	8470.00	1840.00	5220.00	115500.00
1976	27218.02	12068.34	415.33	9205.85	2012.98	5519.06	117377.75
1977	26979.67	13359.75	410.44	9240.77	2034.48	5613.50	118101.69
1978	27626.70	14280.64	405.97	9176.45	2032.65	5661.23	118736.63
1979	27500.39	14334.88	397.46	9257.44	2072.70	5739.10	119557.81
% CHANGE CALCULATED FROM BASE FOR 1979							
	-0.72	-4.28	-0.13	-4.07	-3.60	-1.56	-0.37
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979							
	-0.13	-0.81	0.01	-0.46	-0.47	-0.21	-0.04

LIVESTOCK PRICES

YEAR	BEEF AND VEAL $/LB.	PORK $/LB.	SHEEP AND LAMB $/LB.	CHICKEN $/LB.	TURKEY $/LB.	EGG $/LB.	MILK $/LB.
1973	0.4280	0.3840	0.3530	0.2410	0.3820	0.5410	0.0714
1974	0.3570	0.3430	0.3750	0.2050	0.2830	0.5280	0.0830
1975	0.3200	0.4125	0.3850	0.2600	0.3350	0.5800	0.0855
1976	0.3553	0.4119	0.3881	0.2112	0.2692	0.4827	0.0882
1977	0.4473	0.3161	0.4182	0.1965	0.2758	0.4832	0.0924
1978	0.5214	0.3443	0.4494	0.2113	0.2942	0.5104	0.0976
1979	0.5628	0.3672	0.4748	0.2291	0.3131	0.5260	0.1021
% CHANGE CALCULATED FROM BASE FOR 1979							
	6.1908	11.2591	3.2132	9.0764	7.9699	9.5794	2.1888
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979							
	1.3442	0.5118	0.4946	0.7303	0.8346	0.8729	0.2953

10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES

LIVESTOCK CASH RECEIPTS

YEAR	BEEF AND VEAL M. $	PORK M. $	SHEEP AND LAMB M. $	CHICKEN M. $	TURKEY M. $	EGG M. $	MILK M. $
1973	22738.92	7645.63	383.78	2879.81	933.54	2971.21	8071.18
1974	20595.72	7414.26	424.91	2450.96	726.40	2980.61	8015.32
1975	19491.82	7660.61	373.25	3092.62	770.13	3118.43	9670.24
1976	23280.07	7822.55	372.04	2730.73	677.05	2744.20	10140.35
1977	29055.76	6646.38	396.22	2549.63	701.16	2793.77	10689.35
1978	34679.04	7738.57	421.08	2722.67	747.02	2976.36	11352.04
1979	37263.46	8283.23	435.59	2977.90	810.84	3109.21	11951.86
% CHANGE CALCULATED FROM BASE FOR 1979							
	5.43	6.50	3.07	4.64	4.09	7.87	1.81
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979							
	1.18	0.56	0.47	0.38	0.44	0.80	0.26

PRICES OF FEED GRAINS

YEAR	PRICE OF CORN $/BU.	PRICE OF SORGHUM $/BU.	PRICE OF BARLEY $/BU.	PRICE OF OATS $/BU.	PRICE OF FEED GRAIN $/T.	FRACTION FEED GRAIN SOLD
1973	2.55	2.13	2.13	1.16	92.55	0.62
1974	3.10	3.05	2.95	1.66	131.08	0.67
1975	1.89	1.77	1.44	0.96	65.95	0.68
1976	1.87	1.76	1.43	0.96	65.50	0.67
1977	2.11	1.98	1.60	1.08	73.67	0.66
1978	2.22	2.08	1.69	1.13	77.53	0.65
1979	2.32	2.18	1.77	1.19	81.23	0.65
% CHANGE CALCULATED FROM BASE FOR 1979						
	22.31	24.54	17.92	18.72	22.31	-1.22
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979						
	5.15	5.54	-5.11	-8.31	5.15	-0.38

YEAR	INDEX OF PRICES PAID FOR FEED	INDEX OF PRICES REC. FOR LIVESTOCK	LIVESTOCK PRODUCTION UNITS	BY-PRODUCTS FED M. T.	TOTAL CONCENTRATES FED M. T.	ROUGHAGE FED M. T.	WHEAT FOOD DEMAND M. BU.
1973	307.89	496.00	80.24	34.60	194.60	215.52	530.10
1974	437.52	459.75	82.41	50.40	179.90	212.88	530.00
1975	217.56	466.95	80.52	48.33	203.87	212.62	545.64
1976	211.33	477.15	84.72	50.51	222.22	224.93	538.65
1977	235.22	504.23	86.87	42.52	217.90	229.65	532.82
1978	262.92	559.59	89.23	42.61	219.71	238.95	529.20
1979	300.98	595.79	89.49	44.64	207.08	242.31	526.82
% CHANGE CALCULATED FROM BASE FOR 1979							
	16.14	6.06	-2.12	1.35	-2.12	-0.40	-1.90
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979							
	3.05	0.83	-0.34	0.28	-0.24	-0.07	-0.03

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LIVESTOCK PRODUCTION COSTS

YEAR	TOTAL COST OF PROTEIN M. $	TOTAL COST FEED GRAINS M. $	TOTAL NON-FEED COST M. $	TOTAL COST OF ROUGHAGE M. $	PRICE OF HAY $/T.	VAR. PROD. COST OF HAY $/AC.	FRACTION OF HAY SOLD
1973	8200.79	10051.80	8332.49	4215.44	41.60	10.68	0.20
1974	16423.06	12343.82	9181.51	5430.41	50.70	14.23	0.22
1975	7785.91	7441.30	10054.88	5717.18	50.00	15.92	0.22
1976	7661.84	8036.88	11098.38	5829.56	44.42	16.89	0.22
1977	7069.97	8929.79	11710.73	6176.93	44.76	18.07	0.22
1978	8605.54	9357.10	12439.57	6704.98	45.35	19.34	0.22
1979	11441.80	8929.39	12946.38	7095.63	45.71	20.69	0.22
% CHANGE CALCULATED FROM BASE FOR 1979							
	12.20	8.88	-1.27	0.16	1.59	0.0	-0.50
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979							
	3.40	-0.43	-0.24	-0.05	0.11	0.0	-0.12

DEFICIENCY PAYMENTS

YEAR	CORN M. $	SORGHUM M. $	BARLEY M. $	ALL FEED GRAINS M. $	WHEAT M. $	COTTON M. $	ALL CROPS M. $
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	352.62	179.66	532.27
1976	0.0	0.0	33.94	33.94	0.0	301.57	335.50
1977	0.0	0.0	0.0	0.0	214.35	0.0	214.35
1978	0.0	0.0	0.0	0.0	0.0	705.05	705.05
1979	0.0	0.0	0.0	0.0	189.79	0.0	189.79
% CHANGE CALCULATED FROM BASE FOR 1979							
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979							
	0.0	0.0	6.79	6.79	151.35	237.26	395.39

GOVERNMENT STOCKS

YEAR	FEED GRAINS ENDING YEAR GOVT STOCKS M. T.	WHEAT ENDING YEAR GOVT STOCKS M. BU.	SOYBEAN ENDING YEAR GOVT STOCKS M. BU.	COTTON ENDING YEAR GOVT STOCKS M. BALES
1973	0.0	7.80	0.0	0.20
1974	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.19
1979	0.0	0.0	0.0	0.19
% CHANGE CALCULATED FROM BASE FOR 1979				
	0.0	0.0	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979				
	0.0	0.0	0.0	0.08

10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES

PRODUCTION COSTS

YEAR	TOT VARIABLE PROD COST OF FG,WH,SOY,COT M. $	TOT VARIABLE PROD COST OF LIVESTOCK M. $	TOT OF ALL CROP RECEIPTS M. $	TOT OF ALL LIVESTOCK RECEIPTS M. $	TOTAL CONSUMERS EXPENDITURE M. $
1973	7755.66	30800.52	36049.61	46244.00	138800.00
1974	10990.53	43378.79	49527.00	43108.16	147586.94
1975	11204.29	30999.27	40914.25	44750.36	158132.81
1976	10717.27	32626.66	40980.78	48331.41	165375.13
1977	11507.64	33887.42	43158.43	53416.64	177739.81
1978	12918.79	37107.19	45206.09	61212.14	190821.00
1979	13527.91	40413.20	49009.50	65430.56	202547.88
% CHANGE CALCULATED FROM BASE FOR 1979					
	-19.61	4.71	5.31	4.87	2.13
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979					
	-18.09	0.61	1.03	0.82	0.32

SUMMARY OF RECEIPTS & COSTS

YEAR	TOT OF ALL CROP & LIVESTOCK RECEIPTS M. $	TOTAL OF ALL GOVERNMENT PAYMENTS M. $	TOT OF RECEIPTS AND GOVT PAYMENTS M. $	REALIZED NON-MONEY INCOME M. $	REALIZED GROSS INCOME M. $	TOTAL PRODUCTION EXPENSES M. $	REALIZED NET FARM INCOME M. $
1973	88590.00	2607.00	91197.00	5777.00	96974.00	64746.00	32228.00
1974	92635.13	273.00	92908.13	6466.00	102004.00	74800.00	27204.00
1975	85664.56	732.27	86396.81	8439.99	94836.75	75112.69	19724.06
1976	89312.19	420.69	89732.88	8154.02	97886.88	81945.50	15941.38
1977	96575.06	471.48	97046.50	7280.06	104326.50	86525.75	17800.75
1978	106418.19	857.62	107275.75	7246.91	114522.63	93278.69	21243.94
1979	114440.00	389.79	114829.75	7348.37	122178.06	98850.56	23327.50
% CHANGE CALCULATED FROM BASE FOR 1979							
	5.06	94.90	5.22	0.66	4.94	0.12	31.79
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979							
	0.92	171.66	1.28	0.08	1.20	-0.94	11.94

OTHER RECEIPTS & EXPENSES

YEAR	OTHER CROP (NON-MODEL) RECEIPTS M. $	OTHER LIVEST (NON-MODEL) RECEIPTS M. $	OTHER PRODUCTION EXPENSES M. $
1973	15542.09	619.58	38490.16
1974	17076.00	500.00	41285.98
1975	17759.00	573.28	38693.15
1976	17759.00	564.43	44567.23
1977	18291.00	584.39	47126.22
1978	18839.00	575.37	49781.55
1979	19404.00	598.47	51717.30
% CHANGE CALCULATED FROM BASE FOR 1979			
	0.0	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979			
	0.0	0.0	0.0

10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES

GOVT SET ASIDE PAYMENTS

YEAR	GOVT PAYMENT FEED GRAIN VOL. SET-ASIDE M. $	GOVT PAYMENT WHEAT VOL. SET-ASIDE M. $	GOVT PAYMENT COTTON VOL. SET-ASIDE M. $	GOVT PAYMENT TO CROPS OTHER THAN FG, WHEAT, COTTON M. $
1973	1142.00	474.00	718.00	273.00
1974	0.0	0.0	0.0	273.00
1975	0.0	0.0	0.0	200.00
1976	0.0	0.0	0.0	85.19
1977	0.0	0.0	0.0	257.13
1978	0.0	0.0	0.0	152.57
1979	0.0	0.0	0.0	200.00
% CHANGE CALCULATED FROM BASE FOR 1979				
	0.0	0.0	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979				
	0.0	0.0	0.0	0.0

FEED GRAIN EXOGENOUS DATA

YEAR	ACREAGE SET-ASIDE M. AC.	CORN LOAN RATE $/BU.	CORN NEW LOAN RATE $/BU.	PAYMENT VOLUNTARY SET-ASIDE M. $	IMPORTS M. T.	FOOD, SEED & INDUSTRY DEMAND M. T.	CORN TARGET PRICE $/BU.	ALLOTTED ACREAGE M. AC.	ADMINIS-TRATIVE CORN YIELD BU./AC.
1973	9.42	1.08	1.08	1142.00	0.30	17.30	0.0	114.40	87.00
1974	0.0	1.10	1.10	0.0	0.50	18.10	1.38	87.00	75.00
1975	0.0	1.10	1.10	0.0	0.50	20.73	1.70	89.00	92.00
1976	0.0	1.10	1.10	0.0	0.30	22.16	1.82	88.00	97.00
1977	0.0	1.10	1.10	0.0	0.30	22.90	1.83	89.00	99.50
1978	0.0	1.10	1.10	0.0	0.30	23.55	1.72	90.00	101.50
1979	0.0	1.10	1.10	0.0	0.30	42.18	1.83	91.00	103.00
% CHANGE CALCULATED FROM BASE FOR 1979									
	0.0	0.0	0.0	0.0	0.0	0.0	21.83	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979									
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

WHEAT EXOGENOUS DATA

YEAR	ACREAGE SET-ASIDE M. AC.	LOAN RATE $/BU.	NEW LOAN RATE $/BU.	PAYMENT VOLUNTARY SET-ASIDE M. $	IMPORTS M. BU.	SEED & INDUSTRIAL DEMAND M. BU.	TARGET PRICE $/BU.	ALLOTTED ACREAGE M. AC.	ADMINIS-TRATIVE YIELD BU./AC.
1973	7.37	1.25	1.25	474.00	3.80	83.00	0.0	17.78	31.00
1974	0.0	1.37	1.37	0.0	2.00	87.00	2.05	55.00	27.80
1975	0.0	1.37	1.37	0.0	1.00	84.00	2.55	53.50	32.50
1976	0.0	1.37	1.37	0.0	1.00	82.00	2.74	58.50	33.10
1977	0.0	1.37	1.37	0.0	1.00	80.00	2.82	58.30	33.70
1978	0.0	1.37	1.37	0.0	1.00	80.00	2.74	58.20	34.30
1979	0.0	1.37	1.37	0.0	1.00	80.00	2.91	58.10	34.90
% CHANGE CALCULATED FROM BASE FOR 1979									
	0.0	0.0	0.0	0.0	0.0	0.0	26.49	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979									
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES

SOYBEAN EXOGENOUS DATA

YEAR	ACREAGE SET-ASIDE M. AC.	LOAN RATE $/BU.	NEW LOAN RATE $/BU.	PAYMENT VOLUNTARY SET-ASIDE M. $	IMPORTS M. BU.	SEED, FEED & RESIDUAL USE M. BU.
1973	0.0	2.25	2.25	0.0	0.0	91.20
1974	0.0	2.25	2.25	0.0	0.0	79.00
1975	0.0	2.25	2.25	0.0	0.0	80.00
1976	0.0	2.25	2.25	0.0	0.0	80.00
1977	0.0	2.25	2.25	0.0	0.0	80.00
1978	0.0	2.25	2.25	0.0	0.0	80.00
1979	0.0	2.25	2.25	0.0	0.0	80.00
% CHANGE CALCULATED FROM BASE FOR 1979						
	0.0	0.0	0.0	0.0	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979						
	0.0	0.0	0.0	0.0	0.0	0.0

COTTON EXOGENOUS DATA

YEAR	ACREAGE SET-ASIDE M. AC.	LOAN RATE $/LB.	NEW LOAN RATE $/LB.	PAYMENT VOLUNTARY SET-ASIDE M. $	IMPORTS M. BALES	TARGET PRICE $/LB.	ALLOTTED ACREAGE M. AC.	ADMINISTRATIVE YIELD LB./AC.
1973	0.0	0.19	0.19	718.00	0.07	0.0	10.00	541.00
1974	0.0	0.25	0.25	0.0	0.0	0.38	11.00	442.00
1975	0.0	0.34	0.34	0.0	0.0	0.45	11.00	490.00
1976	0.0	0.37	0.37	0.0	0.0	0.50	11.00	490.00
1977	0.0	0.40	0.40	0.0	0.0	0.53	11.00	490.00
1978	0.0	0.41	0.41	0.0	0.0	0.54	11.00	490.00
1979	0.0	0.42	0.42	0.0	0.0	0.56	11.00	490.00
% CHANGE CALCULATED FROM BASE FOR 1979								
	0.0	0.0	0.0	0.0	0.0	16.56	0.0	0.0
% CHANGE CALCULATED FROM BASE FOR 1975 TO 1979								
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

10 PCT ENERGY PRICE INCREASE, NO CONSTRAINTS OR SHORTAGES

	1975		1976		1977		1978		1979	
	BASE	SIM.	BASE	SIM.	BASE	SIM.	BASE	SIM.	BASE	SIM.
HARVESTED ACREAGE										
FEED GRAINS(M.AC.)	102.60	102.60	103.70	103.09	104.60	103.65	104.90	105.07	106.00	107.31
WHEAT(M.AC.)	67.50	67.50	65.50	64.16	63.70	63.41	61.90	62.02	61.90	62.18
SOYBEANS(M.AC.)	55.50	55.50	55.00	55.92	54.00	54.55	54.00	53.55	57.00	56.22
COTTON(M.AC.)	9.40	9.40	9.50	9.88	9.50	10.09	11.70	12.27	9.90	9.72
PRODUCTION										
FEED GRAINS(M.TONS)	216.90	230.51	230.40	226.49	236.00	226.21	240.90	229.96	247.40	234.28
WHEAT(M.BU.)	2126.00	2298.15	2168.00	2118.24	2147.00	2109.11	2123.00	2044.59	2160.00	2041.12
SOYBEANS(M.BU.)	1500.00	1535.43	1500.00	1525.30	1485.00	1477.94	1510.00	1451.72	1610.00	1532.50
COTTON(M.NET BALES)	9.80	9.37	9.90	9.65	9.90	9.78	12.00	12.87	10.40	7.98
CATTLE(M.CAR.WT.LBS.)	25300.00	25300.00	27000.00	27218.02	27000.00	26979.67	27800.00	27626.70	27700.00	27500.39
PORK(M.CAR.WT.LBS.)	11800.00	11800.00	11600.00	12068.34	13300.00	13359.75	14702.00	14280.64	14976.00	14334.88
SHEEP(M.CAR.WT.LBS.)	420.00	420.00	415.00	415.33	410.00	410.44	406.00	405.97	398.00	397.46
CHICKENS(M.RTE LBS.)	8470.00	8470.00	8890.00	9205.85	9150.00	9240.77	9400.00	9176.45	9650.00	9257.44
TURKEYS(M.RTE LBS.)	1840.00	1840.00	1950.00	2012.98	2020.00	2034.48	2080.00	2032.65	2150.00	2072.70
EGGS(M.DOZ.)	5220.00	5220.00	5440.00	5519.06	5600.00	5613.50	5720.00	5661.23	5830.00	5739.10
MILK(M.LBS.)	115500.00	115500.00	117000.00	117377.75	118000.00	118101.69	119000.00	118736.63	120000.00	119557.81
PRICES										
CORN($/BU.)	2.25	1.89	2.00	1.87	1.90	2.11	1.85	2.22	1.90	2.32
WHEAT($/BU.)	3.15	2.34	2.75	2.86	2.50	2.71	2.50	2.77	2.50	2.82
SOYBEANS($/BU.)	4.00	3.63	3.75	3.60	3.90	3.95	4.40	4.80	5.50	6.09
COTTON($/LB.)	0.39	0.41	0.41	0.44	0.55	0.58	0.45	0.41	0.50	0.64
CATTLE($/LB.)	0.32	0.32	0.38	0.36	0.45	0.45	0.50	0.52	0.53	0.56
PORK($/LB.)	0.41	0.41	0.46	0.41	0.32	0.32	0.32	0.34	0.33	0.37
SHEEP($/LB.)	0.38	0.38	0.40	0.39	0.42	0.42	0.44	0.45	0.46	0.47
CHICKENS($/LB.)	0.26	0.26	0.23	0.21	0.20	0.20	0.20	0.21	0.21	0.23
TURKEYS($/LB.)	0.33	0.33	0.29	0.27	0.28	0.28	0.28	0.29	0.29	0.31
EGGS($/DOZ.)	0.58	0.58	0.53	0.48	0.49	0.48	0.48	0.51	0.48	0.53
MILK($/CWT.)	8.55	8.55	9.00	8.82	9.28	9.24	9.63	9.76	9.99	10.21
CASH RECEIPTS(M.$)	88289.31	85664.56	92518.94	89312.19	95773.19	96575.06	102431.44	106418.19	108930.88	114440.00
CROPS(M.$)	43539.00	40914.25	41775.06	40980.78	42014.98	43158.43	43156.42	45206.09	46539.72	49009.50
LIVESTOCK(M.$)	44750.36	44750.36	50743.92	48331.41	53758.23	53416.64	59275.02	61212.14	62391.18	65430.56
TOTAL GOVT PAYMENTS(M.$)	200.00	732.27	200.00	420.69	257.13	471.48	200.00	857.62	200.00	389.79
FEED GRAINS(M.$)	0.0	0.0	0.0	33.94	0.0	0.0	0.0	0.0	0.0	0.0
WHEAT(M.$)	0.0	352.62	0.0	0.0	0.0	214.35	0.0	0.0	0.0	189.79
COTTON(M.$)	0.0	179.66	114.81	301.57	0.0	0.0	47.43	705.05	0.0	0.0
GROSS FARM INCOME(M.$)	96929.00	94836.75	100918.00	97886.88	103314.00	104326.50	109846.00	114522.63	116430.00	122178.06
PRODUCTION EXPENSES(M.$)	77000.00	75112.69	83900.00	81945.50	87200.00	86525.75	93030.00	93278.69	98730.00	98850.56
NET FARM INCOME(M.$)	19929.00	19724.06	17018.00	15941.38	16114.00	17800.75	16816.00	21243.94	17700.00	23327.50

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	1975		1976		1977		1978		1979	
	BASE	SIM.	BASE	SIM.	BASE	SIM.	BASE	SIM.	BASE	SIM.
EXPORTS										
FEED GRAINS(M.TONS)	42.20	45.61	47.20	49.83	50.70	48.81	54.20	48.18	57.70	49.26
WHEAT(M.BU.)	1125.00	1269.23	1200.00	1223.71	1225.00	1181.34	1250.00	1168.84	1275.00	1167.46
SOYBEANS(M.BU.)	500.00	514.08	560.00	578.96	590.00	591.44	610.00	574.71	625.00	569.76
COTTON(M.NET BALES)	4.00	3.88	4.00	3.81	5.00	4.80	4.50	4.63	4.80	4.16
YIELD/HARVESTED ACRE										
FEED GRAINS(TON/AC.)	2.11	2.25	2.22	2.20	2.26	2.18	2.30	2.19	2.33	2.18
WHEAT(BU./AC.)	31.50	34.05	33.10	33.02	33.70	33.26	34.30	32.97	34.69	32.83
SOYBEANS(BU./AC.)	27.03	27.67	27.27	27.28	27.50	27.09	27.96	27.11	28.25	27.26
COTTON(LBS./AC.)	500.43	478.53	500.21	468.69	500.21	465.22	492.31	503.12	504.24	394.39
LOAN RATES										
CORN($/BU.)	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
SORGHUM($/BU.)	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
BARLEY($/BU.)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
WHEAT($/BU.)	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
COTTON($/LB.)	0.34	0.34	0.37	0.37	0.40	0.40	0.41	0.41	0.42	0.42
TARGET PRICES										
CORN($/BU.)	1.38	1.70	1.58	1.82	1.61	1.83	1.48	1.72	1.50	1.83
SORGHUM($/BU.)	1.31	1.61	1.50	1.73	1.53	1.74	1.41	1.63	1.43	1.73
BARLEY($/BU.)	1.13	1.39	1.29	1.49	1.32	1.50	1.21	1.41	1.23	1.50
WHEAT($/BU.)	2.05	2.55	2.31	2.74	2.38	2.82	2.29	2.74	2.30	2.91
COTTON($/LB.)	0.38	0.45	0.43	0.50	0.46	0.53	0.46	0.54	0.48	0.56
ALLOTTED ACREAGE										
CORN(M.AC.)	61.00	61.00	60.00	60.00	61.00	61.00	62.00	62.00	63.00	63.00
SORGHUM(M.AC.)	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60
BARLEY(M.AC.)	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40
WHEAT(M.AC.)	53.50	53.50	58.50	58.50	58.30	58.30	58.20	58.20	58.10	58.10
COTTON(M.AC.)	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00

VITA 2

Dwight Francis Rychel

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE ECONOMIC IMPACT OF ENERGY ON FOOD PRODUCTION

Major Field: Industrial Engineering and Management

Biographical:

Personal Data: Born in Tulsa, Oklahoma, June 20, 1945, the son of Mr. and Mrs. Robert J. Rychel.

Education: Graduated from Tulsa Central High School, Tulsa, Oklahoma, in May, 1963; received Bachelor of Science degree in Mechanical Engineering from Oklahoma State University in 1970; received Master of Business Administration degree from Florida State University in 1972; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in December, 1975.

Professional Experience: Electronics technician, U.S. Navy, 1963-1966; Engineering Aide, U.S. Corps of Engineers, 1967-1969; Flight Test Engineer, General Dynamics Convair Aerospace, 1970-1973; Graduate Assistant, Oklahoma State University, 1973-1974; Part-time Instructor, Oklahoma State University, 1974-1975.