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RESEARCH REPORT ON DEVELOPMENT OF SWEET SORGHUM AS AN ENERGY CROP

Volume 3: Integration Concepts

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RESEARCH REPORT

on

DEVELOPMENT OF SWEET SORGHUM AS AN ENERGY CROP VOLUME III: INTEGRATION CONCEPTS

to

U.S. DEPARTMENT OF ENERGY

DECEMBER 12, 1980

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P.G. Woodford, E.J. Honton, and E.S. Lipinsky

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FOREWORD

Background

Development of renewable sources of liquid fuels in the U.S. is necessary to reduce dependence on imported oil. The constant rise in OPEC oil prices coupled with an oil import tax and price deregulation of new domestic oil provides the necessary economic incentives to produce ethanol fuel from agricultural raw materials. Legislative action in the next 12 months may also provide guaranteed loans and grants through a "Synfuels Bill" for the great amounts of venture capital necessary for a rapidly expanding biomass fuels industry.

After imposing a U.S. grain embargo on the U.S.S.R., President Carter stated that resulting excess domestic grain supply could be converted to fuel-grade ethanol through a government-backed expansion of the alcohol industry (Carter, 1980). Thus, for the next 3-5 years, if surpluses continue to remain high, conventional grain crops will be the most likely carbohydrate feedstocks used to produce ethanol.

In the long-term (10-20 years), as world-wide petroleum supplies dwindle and as food demand increases, new energy crops through innovative conversion technologies must replace grains as the primary feedstock for biomass fuel production. Sorghum cultivars offer considerable promise as a large-scale energy crop based on the following advantageous characteristics:

- Genetic Diversity - Over 17,000 lines of sorghum exist in the world collection.
- Climatic adaptation - Sorghum can be grown in any of the agricultural regions of the continental U.S.
- Biomass - Sorghum, if climatically adapted, can compete in photosynthate production with any conventional crop currently grown in the U.S.
- Production economics - Most sorghum is drought tolerant and efficient in nutrient use which lowers production input costs without sacrifices in yield.

Sweet sorghum and its genetic relatives are among the least exploited agronomic crops but are highly promising for fuels production provided that seasonality problems affecting processing and conversion economics can be overcome. Rapid exploitation of existing sweet sorghum lines and the development of new hybrids could reduce substantially the land requirements necessary to meet biomass fuel goals for the next 20 years.

For the past 3 years, Battelle's Columbus Division and several co-investigators have conducted interregional investigations related to biomass and sugar production for conversion to alcohol and other fuels. These investigations have emphasized primarily the production of sweet sorghum and sugarcane due to their ability to produce high biomass and readily fermentable sugars' yields which allow a highly favorable energy balance when converted to ethanol.

Description of Sweet Sorghum

Sweet sorghum is a member of the grass family and is closely related to grain sorghum, broomcorn, Johnsongrass, and Sudan grass. Sweet sorghum plants are slow to develop after germination, especially in soil having temperatures below 60°F. This characteristic means that sweet sorghum develops slower than other crops in the more northerly regions of the U.S. However, after the plant is established, it grows very quickly with sufficient moisture. As with other sorghums, sweet sorghum is drought tolerant and is adaptable to most major agricultural regions of the United States.

Sweet sorghum grows to a height of 12-14 feet with a maximum stem diameter of 1-2 inches at maturity. Sweet sorghum produces a seed head at the tip of the plant which ripens 100 to 150 days after planting. Fermentable sugars begin to accumulate in the pithy stalk when the seed is in the soft dough stage. Stalks can be harvested after maximum sugars accumulation, usually occurring from the hard dough to ripe stage. Stalks are very fibrous and may be used for fuel, or for the manufacture of press board if the pith is cleanly separated. As cellulose conversion-to-alcohol technologies are developed, the fibrous portion of the stalk also could represent an alcohol feedstock.

Although sweet sorghum hybrids have not been developed, several high-producing cultivars have been released for commercial use from the U.S. Sugar Crops Field Station at Meridian, Mississippi. Among these, Wray, Rio, and Dale appear to be most widely adapted to the mid-western and Great Plains regions. Biomass and sugar yields for Wray ranged from 6.2 to 12.9 and from 2.7 to 4.9 tons/acre respectively, from a single crop in 1979 (Lipinsky, et al). Accordingly, Wray was selected to be grown at all sites in 1979.

Objectives and Scope

The primary goal of the 1979 research program was to determine the agronomic and economic feasibility of developing sweet sorghum, sweet sorghum hybrids, and sugarcane as energy-producing crops in selected geographic regions of the United States.

The objectives of research reported in Volume III, "Integration Concepts", include the following:

(1) To conduct a prefeasibility analysis of the potential for integrating sugarcane and sugar beet production/processing with sweet sorghum

(2) To formulate an analytical approach to estimate the economic impact of growing sweet sorghum as an energy crop upon the U.S. agricultural system.

The objectives of the studies reported in Volume II, "Commercialization Studies" (this volume), include the following:

(1) To identify and evaluate the ease of commercialization of sweet sorghum by monitoring trial crop production by interested farmers

(2) To investigate the economics of sweet sorghum production, competitive prices and yields, and marginal costs and returns of production

(3) To identify, investigate, and evaluate key marketing and organizational considerations in utilizing sweet sorghum as a renewable resource for fuel production

(4) To assess the availability of water for production of additional sugarcane and/or sweet sorghum in Southern Florida and the Texas Rio Grande Valley.

The objectives of the agronomics studies, reported in Volume I, "Agricultural Research", included the following:

(1) Determine response of sweet sorghum to major latitudinal and longitudinal gradients in the U.S. in terms of biomass and sugar production and plant composition

(2) Determine optimal cultural practices and select outstanding cultivars of sweet sorghum and sweet-grain sorghum hybrids

(3) Continue experiments evaluating the potential of sugarcane for energy production in portions of Louisiana and Florida.

Approach

The research reported in Volumes II and III was conducted at Battelle Columbus Division (BCD) principally by staff in the Technical Economics and Business Planning Section. Research support was provided by Mr. Stephen Kresovich in Battelle's Bio-Environmental Section; Mr. Edward Honton of Battelle's Economics, Planning, and Policy Analysis Section; and others.

This research focuses primarily on various micro-and-macro economic issues associated with the commercialization of sweet sorghum. Ultimately, if sweet sorghum, or any other crop, is to be utilized as a resource for fuels or chemical feedstock production, it will be necessary for the producer to obtain a net income equal to or greater than that from alternative land uses. Also, the risk of crop failure, market avaliability and size, equipment requirements, etc., must be compatible with anticipated profit levels. In extending the work previously conducted by Battelle for the U.S. Department of Energy, these results hopefully should provide a better understanding of the potential for sweet sorghum as a commercial crop in various regions of the United States.

Organization and Management Plan

The program organizational structure is shown in Figure 1, Mr. Edward S. Lipinsky, Program Manager was responsible for the overall management of the program. Dr. W. T. Lawhon provided advisory and administrative input to the effort.

Dr. T. A. McClure served as leader of the agricultural economics tasks reported in Volumes II and III (this volume). Mr. D. A. Scantland was the coordinator of the Farm Bureau studies (Volume II) and the principal investigator of the work on integrating alcohol fuels production from sweet sorghum with other crops (Volume III). Dr. William E. Riddle was leader of the task to formulate an analytical approach to estimating the economic impact of growing sweet sorghum upon the U.S. agricultural system (reported in Volume III). He was assisted by Mr. Edward Honton and Ms. Pierrette Woodford in this task. Ms. Woodford also contributed to the water availability studies reported in Volume II, along with Mr. Stephen Kresovich. Mr. William Gordon contributed to the production economic studies reported in Volume II.

Dr. D. R. Jackson was responsible for the development activities at various co-investigator locations, and Mr. M. F. Arthur and Mr. Kresovich were responsible for the direction of agronomic research at Battelle's Bio-Environmental Laboratory. The results of these studies were reported in Volume I.

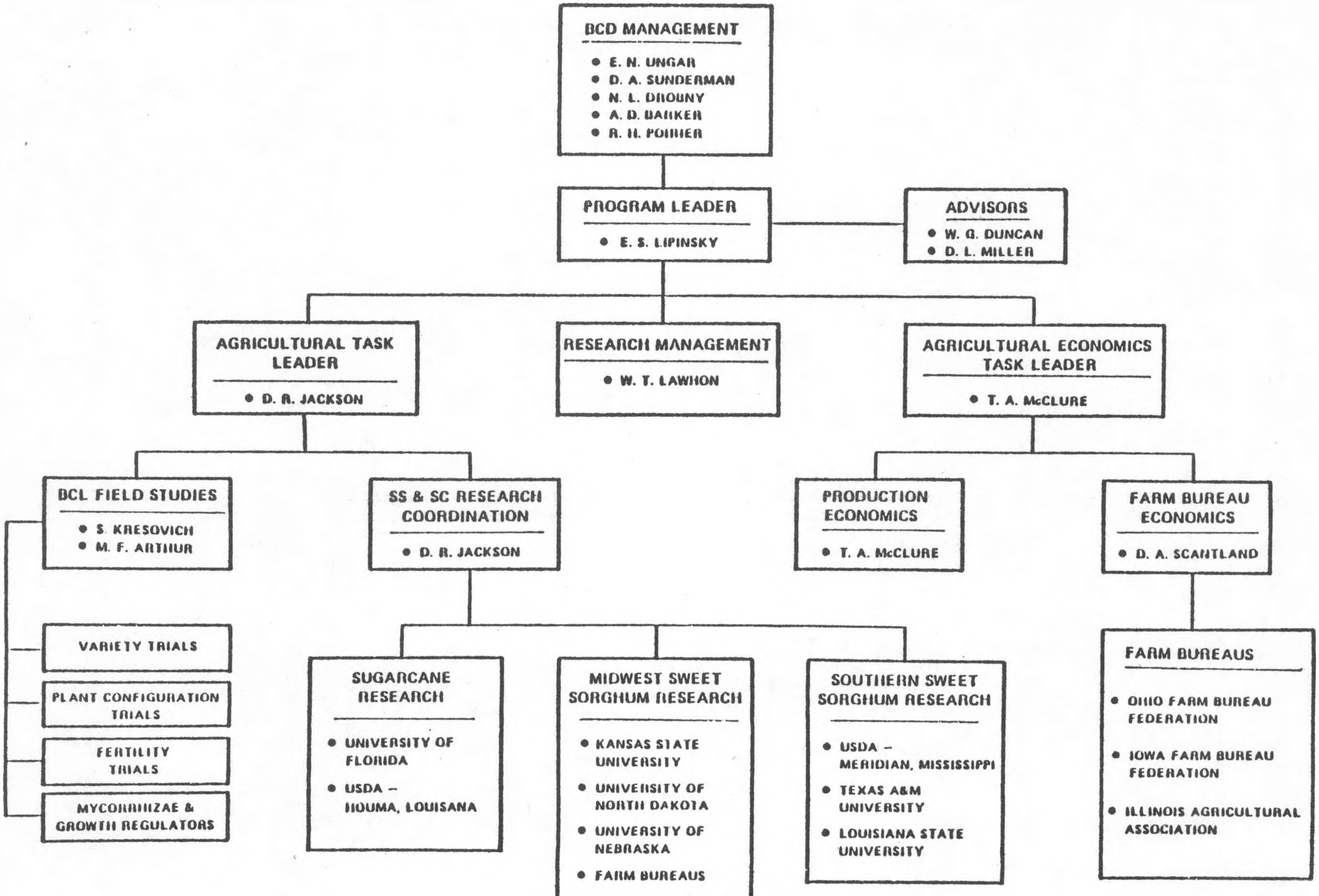

FIGURE 1. AGRICULTURAL TECHNOLOGY PROGRAM ORGANIZATION STRUCTURE

Reporting Format For Volume III. Integration Concepts.

Volume III is comprised of two separate investigations pertaining to potential integration of sweet sorghum into U.S. agriculture. The first investigation entitled, "Economic Potential for Integrating Alcohol Fuels Production from Sweet Sorghum with Other Carbohydrate Crops" conducted independently, looks at integration of sweet sorghum from a microeconomic viewpoint, i.e., what would be the effects of combining sweet sorghum with other sugar crops to produce alcohol in terms of plant investment and operating costs. This study is reported beginning on the following page.

The second investigation, entitled, "Systems Analysis Formulation for Estimating Impacts of Sweet Sorghum Upon United States Agriculture" looks at integration from a macroeconomic viewpoint, i.e., total acreage, total output, general price levels, etc. These results are reported beginning on page 61.

EXECUTIVE SUMMARY

Economic Potential For Integrating Alcohol Fuels Production From Sweet Sorghum With Other Carbohydrate Crops

Integration of sweet sorghum with other carbohydrate crops processing is one potential means of reducing biomass raw material costs. Integration extends the processing season thereby reducing per unit fixed costs. Also, much of the equipment already in-place can be used with the new crop allowing incremental capital investment to be low. About 80 percent of the investment in a sugar crop fermentation unit is with front-end equipment.

This report analyzes three integration alternatives:

- sweet sorghum, sugarcane, and sugar beet agriculture and processing in California
- sweet sorghum and sugarcane agriculture and processing in Louisiana
- sweet sorghum and sugar beet agriculture in Ohio.

The amount of extension of the processing season differs under the three alternatives. In California, traditional sugar beet processing runs the season to a total of 300 days, or a 233 percent (300/90) extension. Only 20 days presumably could be added to the base 90 day Louisiana sugarcane processing season (110/90), or 22 percent. The addition of sweet sorghum to sugar beet processing in Ohio would add 30 days for a total of 140 days; this would be a 27 percent (140/110) increase in the processing season length. Extension of the processing seasons by the above amounts reduces fixed overhead costs by the inverse of the processing season extension minus 1. For example, in California the reduction in fixed overhead costs is $1 \div [(300/90) - 1]$.

Estimated raw material costs for ethanol for the integration systems ranged from a low of $0.87 to a high of $2.03 per gallon. With one exception, the longer the processing season the lower the raw material costs.

Estimated capital investment costs for the ethanol production facilities ranged from a low of $0.68 to a high of $1.43 per annual gallon of ethanol output. Due to the great degree of site specific requirements in investment, the estimated investment costs bear little relation to size of output.

Production costs for ethanol (including return on equity, depreciation, and interest) are estimated to range from $1.55 to $2.73 per gallon. These costs exclude credits (or disposal charges) for by-products. The principal conclusion is that under some situations ethanol from integrated sugar crop systems can be competitive with existing prices for ethanol from grain (about $1.80 per gallon).

Although it is very difficult to extrapolate integrated systems over a wide (U.S.) scale, due to the great site specificity, under certain assumptions it is conceivable that about 200 million gallons of anhydrous ethanol might be able to be produced annually.

ECONOMIC POTENTIAL FOR INTEGRATING ALCOHOL FUELS PRODUCTION FROM SWEET SORGHUM WITH OTHER CARBOHYDRATE CROPS

Introduction

One of the major deterrants to commercialization of sweet sorghum as an energy crop is the present necessity to remove sugars from the stalk immediately after harvest. The perishability of the fermentable sugars fraction of the sweet sorghum crop means that in most areas of the U.S., fermentable sugars extraction (processing) and fermentation (conversion) would occur over about a 60 to 90 day period. Battelle and others currently are exploring various mechanisms to lengthen the processing and conversion seasons. While some successes have been achieved from technical standpoints, the economics of these systems have not been encouraging.

As a result of the short sweet sorghum processing and conversion season, capital facilities and equipment, if built, would be idle for at least three-fourths of the year. In addition the facilities and equipment would be "oversized", so that they could process and convert the year's crop over a two to three month period. Idle and oversized capital resources leads to high average fixed costs per unit output, and hence, high ethyl alcohol costs. Idle facilities and equipment also underutilizes productive resources, which tends to contribute to a variety of socio-economic ills such as inflation, underemployment, and low productivity.

It should be noted that it is not uncommon for capital resources to lay idle, especially in the agricultural and food industries. Examples would include the sugar beet and sugarcane, and vegetable and fruit processing industries. Farming in general has considerable resources that remain idle; planting machinery and combine grain harvesters are used only during several weeks of the year.

One potential means of reducing the severity of the problems associated with sweet sorghum stalk juice perishability and underutilized resources is to integrate sweet sorghum with other carbohydrate crop agriculture, processing, and conversion to extend the season. If feasible, extension of the season would offer a number of clear benefits:

- Lower fuel product (ethanol) costs as fixed costs are spread over more units and/or more days of the year
- Lower by-product costs leaving greater margins
- Lower feed and food (e.g., crystalline sugar) costs
- More efficient utilization of land, labor, and capital resources.

In addition, desugared sweet sorghum stalks could be used as a fuel for process operations, or sold as a fibrous material for various uses including animal feed, or fiberboard manufacture.

Objectives and Scope

The overall objective of this study was to determine the economic potential for integrating sweet sorghum agriculture and processing into present sugarcane, sugar beet, and corn agriculture and processing. Lesser emphasis was placed on the sweet sorghum--corn integration system.

Additional objectives of the study included the development of conceptual models for the various integration alternatives. The models address cost, investment, and time as variables in determining the potential economic competitiveness of an integration system. Gross and net incomes to growers and processors are calculated under hypothetical integrated operations. Finally, quantities of ethyl alcohol are estimated that might be able to be produced under the more favorable integration alternatives.

It should be noted that the scope of this program included only the continental United States, and addresses only a limited number of integration possibilities. There are many other integration alternatives using a wide variety of agricultural raw materials; some of which may prove to be economically feasible. Also, the results of this analysis are based on "representative" growers and processors as opposed to a national sample average. Geographic differences and peculiarities, as well as individual firm differences will not necessarily enable the results of the study to be valid across the wide spectrum of firms and regions. Nonetheless, the study presents a format and research approach that could be used by or for individual firms to estimate the economic and technical attractiveness of integration.

Research Approach

The research approach for this study consisted of seven basic tasks:

(1) A representative sugar beet processor and sugarcane mill were selected as the case studies for the sweet sorghum integration concept. A grain merchandiser also was selected to represent the sweet sorghum/corn integration alternative. The processors selected for each industry depended upon the degree to which they were representative of each industry and their willingness to provide essential information.

(2) Meetings were held with the processors to discuss the integration concept in detail, and to define the type of information to be provided by each firm

(3) Commercial growers were interviewed to elicit reactions regarding the commercializability of sweet sorghum, and the costs of production. The growers' contribution enabled the identification of key obstacles to success.*

(4) Conceptual models for an integrated sweet sorghum/sugar beet, sweet sorghum/sugarcane, and sweet sorghum/sugarcane were developed. Each model consists of a grower segment and a processor segment including incomes, costs, and a flowsheet of activities throughout the year.

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* See T.A. McClure, et al, Development of Sweet Sorghum As An Energy Crop, "Volume II: Commercialization Studies" to U.S. DOE, Battelle Columbus Division, July 31, 1980.

(5) Income components for the grower and processor segments then were tied together. Grower income was estimated given an assumed number of acres grown multiplied by the product of yield and price received. The number of days over which the processor could handle sweet sorghum was determined as well as the tonnage per day. This amount then was translated to an equivalent amount of ethanol at a competitive selling price. Revenue from the alcohol constituted gross income to the processor.

(6) Incomes to growers and processors then were integrated and compared with the existing single crop industry as the primary determinant of the economic attractiveness.

(7) Among those integration alternatives appearing attractive, estimates were made of the potential volume of energy (as ethyl alcohol) that could be produced on a national basis. This involved identifying those regions where similar circumstances (climate especially) occur.

The research approach is illustrated in Figure 2.

*SB--SUGAR BEET

*SC--SUGARCANE

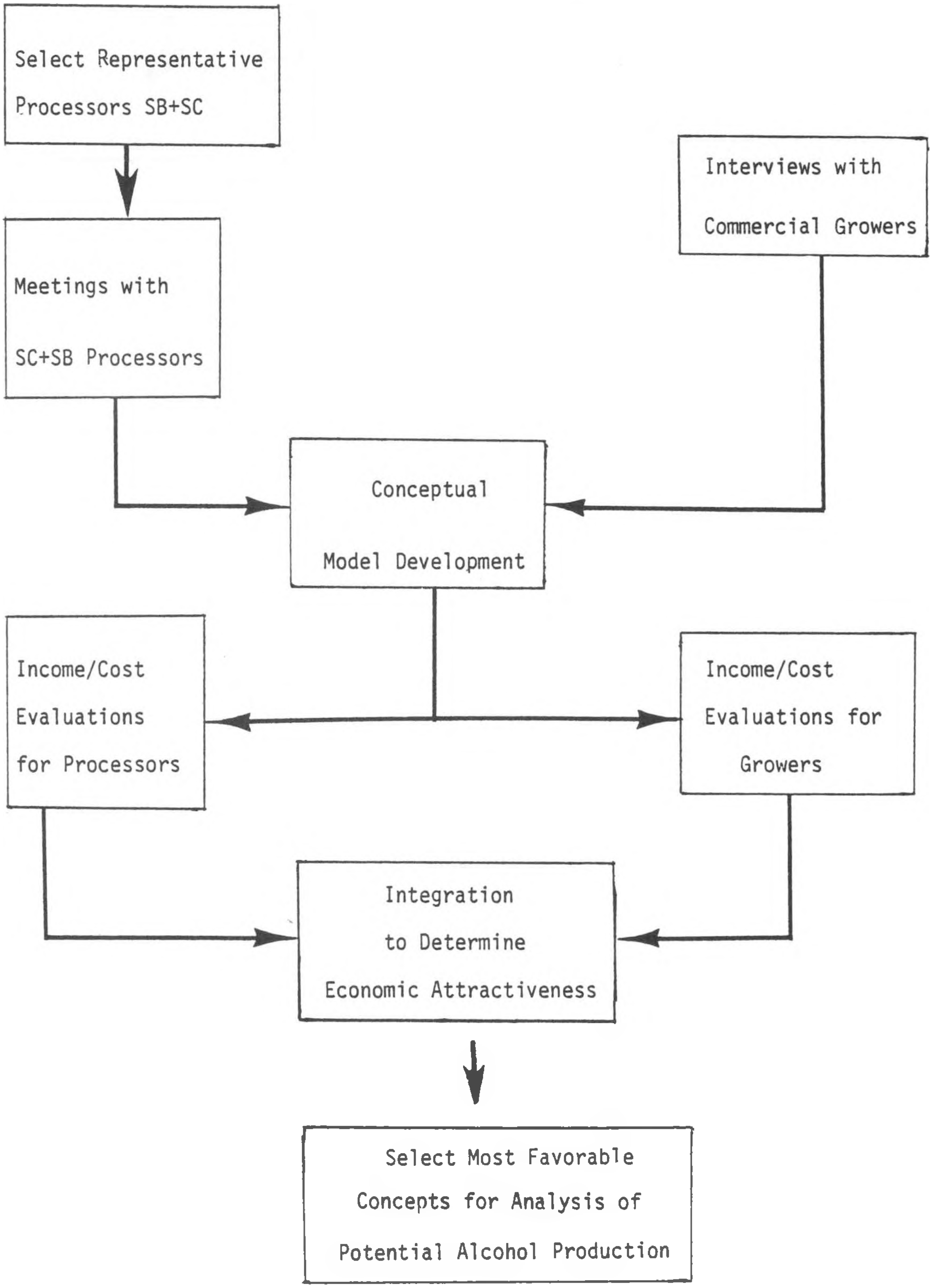

FIGURE 2. RESEARCH APPROACH

INTEGRATION ALTERNATIVES

There are a large number of integration alternatives available to select from when dealing with corn, sweet sorghum, sugarcane, and sugar beets. Six integration concepts were investigated during the course of this research. The six alternatives are presented in Figure 3. Of these six alternatives, three were selected. The three selected alternatives include an Ohio-based sugar beet and sweet sorghum integration (Integration A in Figure 2). A California sugar beet, sugarcane, and sweet sorghum integration (Integration B) and; a Louisiana sugarcane and sweet sorghum integration (Integration D). The Ohio and California integration concepts are based on the existing sugar beet processing facilities, while the Louisiana integration alternative is based on sugarcane processing. The actual processing facilities used for the analyses are reasonably representative of the industries as a whole. More detailed descriptions of the integration alternatives are located in the "Conceptual Models" chapter of this report.

Industry Descriptions

The following paragraphs describe the existing sugar beet and sugarcane industries. The purpose of including this information for readers is to illustrate the representativeness of the processing facilities utilized in the analysis of the integration concept. If the integration concepts are technically and economically viable, estimates then could be made regarding the amount of ethanol able to be produced under more widespread adoption. However, despite the fact that the facilities used in the analyses are representative of the industry averages, the ability to integrate successfully very likely will remain site specific.

Sugar Beet

Currently, sugar beets are grown in approximately 16 states, but in numerous concentrated production areas as shown in Figure 4. In 1979, sugar beets were harvested from 1.12 million acres (Table 1). The average yield for the United States in the same year was 19.6 tons of beets per

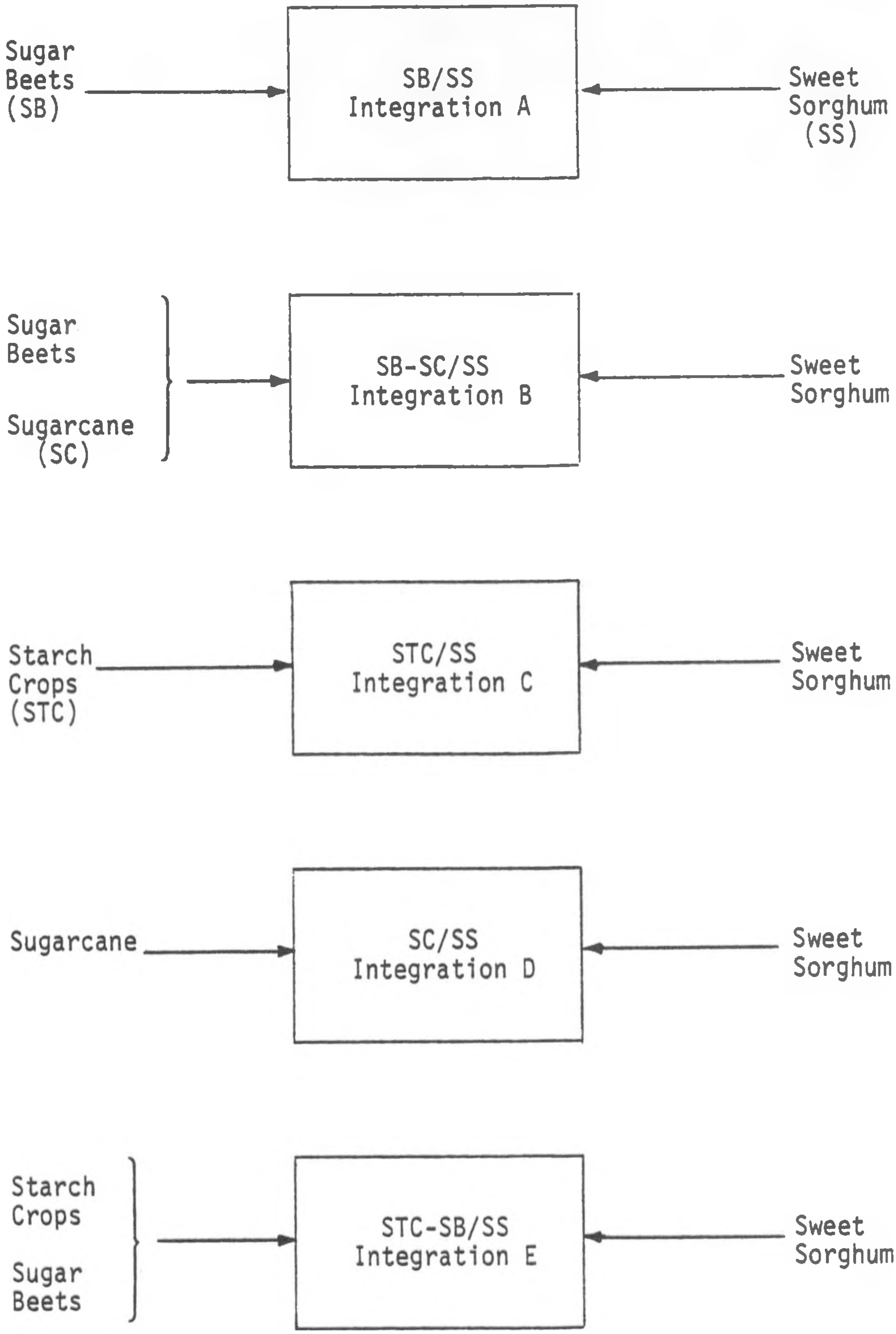

FIGURE 3. INVESTIGATED INTEGRATION CONCEPTS.

TABLE 1. SUGAR BEETS: AREA, YIELD, PRODUCTION, AND SEASON AVERAGE PRICE TO FARMERS, 1970-1979

Year	Area Harvested 1,000 Acres	Yield/Acre Tons Beets/Acre	Production 1,000 Ton Beets	Price[a] $/Ton Beets	Production 1,000 Tons Ref. Sugar
1970	1,413	18.7	26,378	$14.80	3,179
1971	1,342	20.2	27,096	15.40	3,320
1972	1,329	21.4	28,410	16.00	3,387
1973	1,217	20.1	24,499	29.60	2,990
1974	1,213	18.2	22,123	46.80	2,725
1975	1,517	19.6	29,704	27.60	3,756
1976	1,479	19.9	29,386	21.00	3,640
1977	1,216	20.6	25,007	24.20	2,905
1978	1,269	20.3	25,725	25.20	3,075
1979	1,120	19.6	21,996	N.A.	2,697

Source: USDA, Agricultural Statistics, 1978, U.S. Government Printing Office, Washington, D.C. 1978

(a) Does not include government payments under The Sugar Act.

acre. However the range in the yield is quite large, as Table 2 indicates, with Oregon achieving a 16.9 tons per acre yield while Washington averaged 26.5 tons per acre. Total production of sugar beets in 1979 was approximately 22 million tons. From the 22 million tons of beet roots harvested, 2.7 million tons of refined sugar was manufactured. The average price per ton of beets in 1978 was $25.20 per ton. The price per ton is not available for 1979.

The 22 million tons of beets produced in 1979 were processed through approximately 35 sugar beet plants located throughout the United States. At present, an additional 17 processing plants are closed due to low returns on investment during recent years. Average daily capacity among beet plants throughout the United States is close to 4,000 tons per day. On average, a sugar beet plant operates for 120 days out of the year; however, the range is quite wide. In some locations the processing season is only 80 to 100 days (e.g., Michigan and California) while in others 160 to 180 days (e.g., N. Dakota and Minnesota).

Beet processors assure themselves a ready supply of beets during the processing season through contracts with independent growers. Typically, the contracts are written for a specified acreage to be planted in beets. The processors pay the growers for beets grown on the contracted acreage on a tonnage basis; the price per ton received by growers determined by the net returns to processors after deduction of processing and marketing costs.

There are six key steps in sugar beet processing beyond detrashing and washing. The first step is diffusion of sliced sugar beets (cossettes) to remove the sugars from the beets. While there are several different types of diffusors available, all operate under one basic principal. Hot water is injected into a moving flow of cossettes in order to leach out sugars from the cells. The sugar-containing juices are evaporated and the dry residual sucrose is crystallized. The de-sugared cossettes, or beet pulp, is pressed, dried, and normally pelleted. Beet pulp is sold for animal feed. The non-crystallizable protion of the sugars contained in the sugar beet root are spun out of the crystallizer as molasses. Molasses is used as animal feed, for alcohol yeast manufacture, and through a different process often is de-sugared and recrystallized as table sugar.

TABLE 2. SUGAR BEET: AREA, YIELD, AND PRODUCTION BY STATE, 1978 AND 1979.

State	Area Harvested 1,000 Acres		Yield/Acre Tons/Acre		Production 1,000 Tons		Price $/Ton	
	1978	1979	1978	1979	1978	1979	1978	1979
Arizona	15.7		20.5		308	219	25.00	NA
California	207.0		24.5		4,778	5,731	25.80	
Colorado	89.0		18.3		1,538	1,358	27.60	
Idaho	136.3		20.3		2,722	2,804	27.70	
Kansas	28.0		17.0		442	213	21.50	
Michigan	93.0		19.3		1,756	1,558	23.50	
Minnesota	265.0		18.9		4,971	3,782	21.80	
Montana	45.4		19.8		885	829	29.90	
Nebraska	79.0		18.0		1,368	1,460	27.80	
N. Dakota	156.2		19.7		3,054	2,304	22.90	
Ohio	24.5		16.9		394	266	25.10	
Oregon	9.2		24.0		314	175	26.00	
Texas	28.0		17.6		414	332	24.50	
Utah	14.9		17.0		250	29	29.00	
Washington	69.2		26.5		1,815	1,750[(a]	26.80	
Wyoming	49.5		18.9		922	906	29.50	
U.S. TOTAL	1,312.0		20.3		25,868	23,746	25.20	NA

[(a] Estimate only of Washington state production.

Source: USDA, Sugar and Sweetener Report, SSR 5/5. ESCS Washington, D.C., May, 1980.

FIGURE 4. GEOGRAPHIC RANGE OF SUGAR BEET PRODUCTION, 1977.

It is important to note that if alcohol were to be made from sugar beet juices, only limited juice purification would be required before the juice is evaporated, or goes to the fermentation vessels. Under ideal circumstances no evaporation or crystallization would be necessary. The lack of necessity to go to evaporation or crystallization is a particularly important advantage as an estimated 50% of the fuel used in sugar beet processing plants is consumed in these two operations.

Sugarcane

Sugarcane is grown in four states: Florida, Louisiana, Texas, and Hawaii as illustrated in Figure 5. Approximately 27 million tons of sugarcane from 692,000 acres were processed in 1979. The average yield in the United States was 38.4 tons per acre (Table 3). This report deals only with the continental United States. Therefore, it is important to show the relationship between the mainland states growing sugarcane, and Hawaii. Within the continental United States, 589,000 acres of sugarcane were harvested producing some 16.5 million tons of sugarcane in 1979 (Table 4). Mainland sugarcane accounts for approximately 62 percent of the total U.S. production. The average yield within the mainland production areas in 1979 was 28.1 tons per acre. In 1978, continental U.S. sugarcane producers received $19.40 per ton for sugarcane. No estimate is available for 1979.

There are approximately 38 sugarcane processing plants (mills) within the continental United States. The average sugarcane mill processes just under 4,000 tons of cane per day over an average 110 day processing season. The Louisiana production area tends to be on the shorter side of the average with most Louisiana mills operating between 85 and 95 days per year. Excluding cooperatives, most sugarcane mills assure themselves an available supply of sugarcane through contractual arrangements whereby farmers are paid on standard ton basis adjusted for sucrose, ash, and trash levels.

FIGURE 5. GEOGRAPHIC RANGE OF SUGARCANE PRODUCTION, 1977.

TABLE 3. SUGARCANE: AREA, YIELD, PRODUCTION, AND SEASON AVERAGE PRICE TO FARMERS, 1970-1979

Year	Area Harvested 1,000 Acres	Yield/Acre Tons Cane/Acre	Production 1,000 Tons Cane	Price[a] $/Ton Cane	Production 1,000 Tons Ref. Sugar
1970	551	41.8	23,055	$10.50	2,258
1971	607	38.1	23,145	11.10	2,277
1972	664	41.0	27,239	11.60	2,561
1973	703	35.5	24.924	20.90	2,383
1974	690	34.8	24,031	48.50	2,347
1975	735	37.2	27,306	19.60	2,743
1976	704	38.2	26,919	13.70	2,546
1977	719	35.8	25,730	18.50	2,508
1978	709	35.5	25,873	19.40	2,460
1979	692	38.4	26,587	N.A.	2,564

Source: USDA, Agricultural Statistics, 1978, U.S. Government Printing Office, Washington, D.C. 1978

(a) Does not include government payments under The Sugar Act.

TABLE 4. SUGARCANE: AREA, YIELD, AND PRODUCTION BY STATE 1978-1979

State	Area Harvested 1,000 Acres 1978	Area Harvested 1,000 Acres 1979	Yield/Acre Tons/Acre 1978	Yield/Acre Tons/Acre 1979	Production 1,000 Tons 1978	Production 1,000 Tons 1979	Price $/Ton 1978	Price $/Ton 1979
Florida	296.0	315.0	30.8	33.8	9,117	10,647	20.50	NA[d]
Louisiana	278.0	243.0	21.0	20.5	5,838	4,981	18.90	NA
Texas	33.0	31.5	31.1	29.0	1,051	914	11.00	NA
Mainland U.S.	607.8	589.5	27.6[a]	28.1[a]	16,006	16,542	19.40	NA
Hawaii	101.2	102.4	97.5[b]	98.1[b]	9,867	10,045	NA	NA
Total U.S.	709.0	691.9	36.5[c]	38.4[c]	25,873	26,587	NA	NA

(a) Weighted mainland average assuming 12-month growing period.

(b) Yield over 18-24 month growing period.

(c) Weighted U.S. average assuming 12-month growing period on Mainland, and, assuming 21-month growing period in Hawaii annualized to 12-month period, i.e., (97.5) ÷ (21/12) = 55.7 tons per acre per year. Hawaiian harvest occurs throughout year. USDA yields are calculated somewhat differently; USDA quotes yield of 35.5 and 38.4 tons/acre, respectively in 1978 and 1979.

(d) NA--not available.

Source: U.S.D.A., Agricultural Statistics, 1978, U.S. Government Printing Office, Washington, D.C., 1978.

Two major operations separate sugarcane from sugar beet processing. The extraction of sucrose in a sugarcane mill is accomplished through roller milling rather than diffusion. Also, most sugarcane mills are not producing refined sugar; rather they produce raw sugar (unbleached large granuled sucrose). Most raw sugar then is shipped to refiners for bleaching, grinding, and packaging. If fuel grade ethanol were to be made from sugarcane juice, the juice could be diverted from the standard procedures (used to produce crystalline sugar) after roller milling and some clarification. Again, (as with the sugar beet industry) this is important as a major segment of the energy cost in sugarcane processing consists of evaporation and crystallization.

IMPLICATIONS OF THE INTEGRATION CONCEPT

As stated earlier, three integration concepts were selected for detailed analysis. To determine the viability of these concepts, it is necessary to construct a conceptual model of the costs associated with the three systems. However, comments of a more general nature should now be made about all three integration systems regarding the overall implications of the integration concept.

Timing of Operations

Based on the research, it appears that fermentable sugars from sugar crops could be available for 300 days in the southern California area, 110 days in the Louisiana sugarcane area, and 140 days in the Ohio sugar beet area. The availability of the fermentable sugars for each of the three areas is diagrammed in Figures 6 through 8. One of the factors to success in an integration concept is that the supplemental crop does not interfere with the existing agricultural, or more importantly, processing operations.

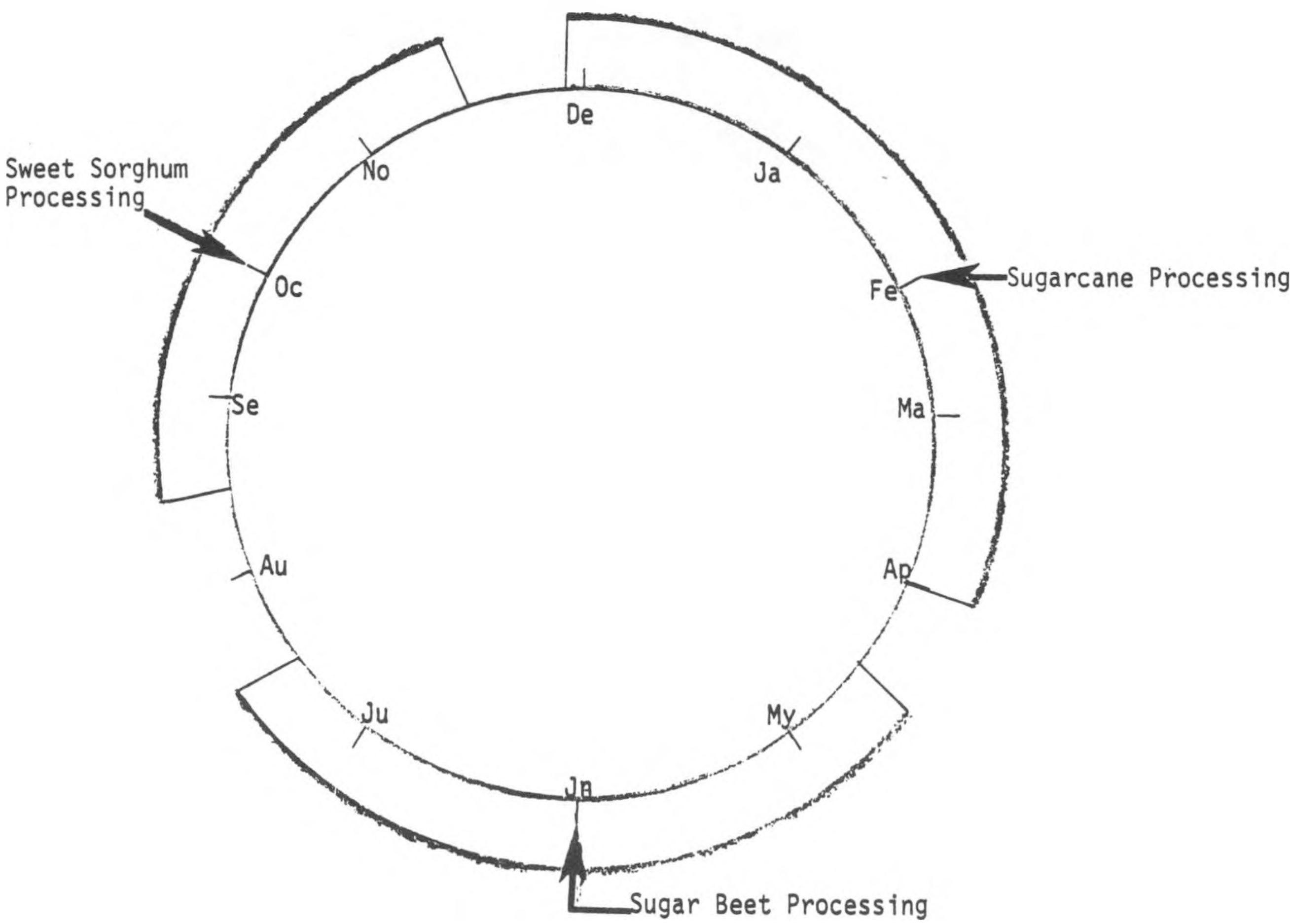

FIGURE 6. MOST LIKELY INTEGRATION SYSTEM--
IMPERIAL VALLEY, CALIFORNIA*

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* Normal (Sugar Beet) processing season is 90 days. Integrated processing season potentially 300 days.

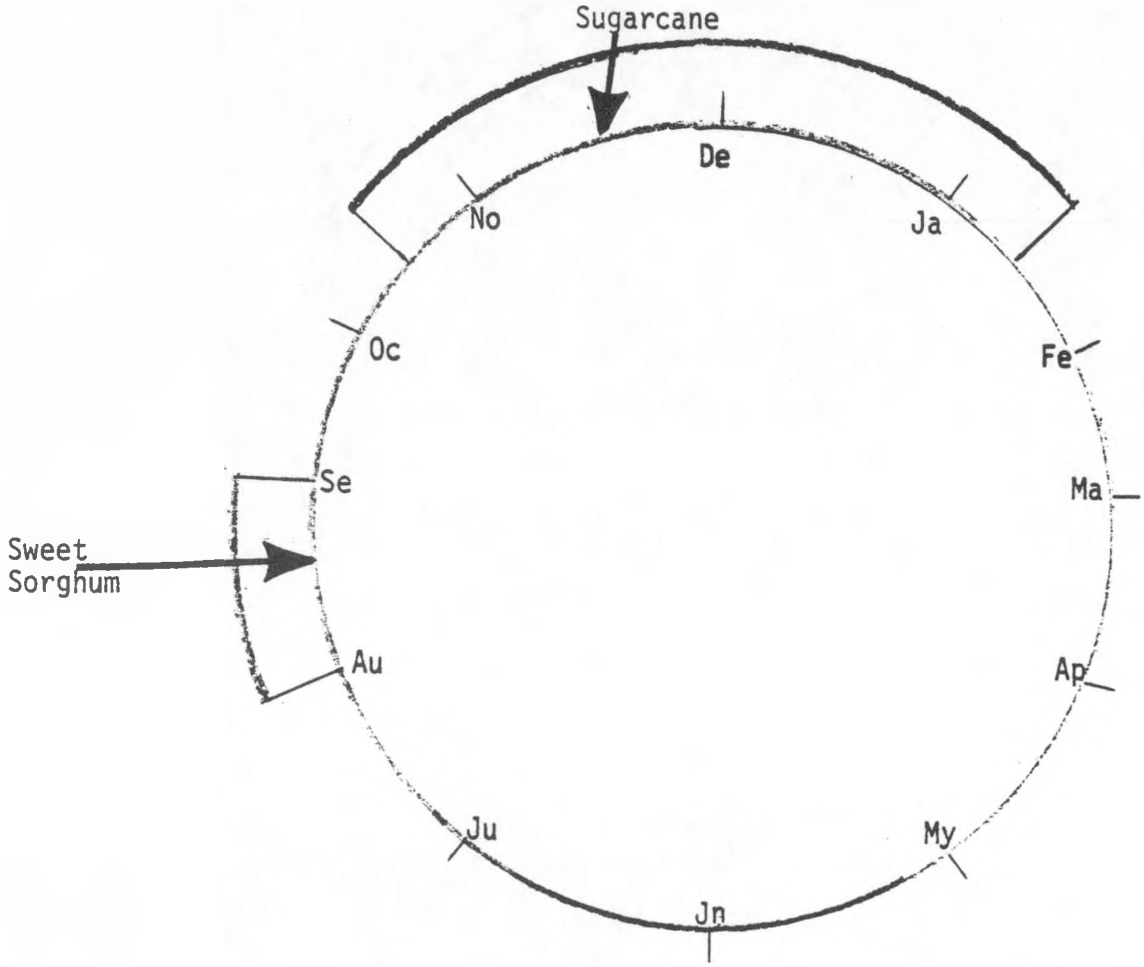

FIGURE 7. MOST LIKELY INTEGRATION SYSTEM--SOUTHERN LOUISIANA*

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* Normal (Sugarcane) processing season is 90 days. Integrated processing season potentially 110 days.

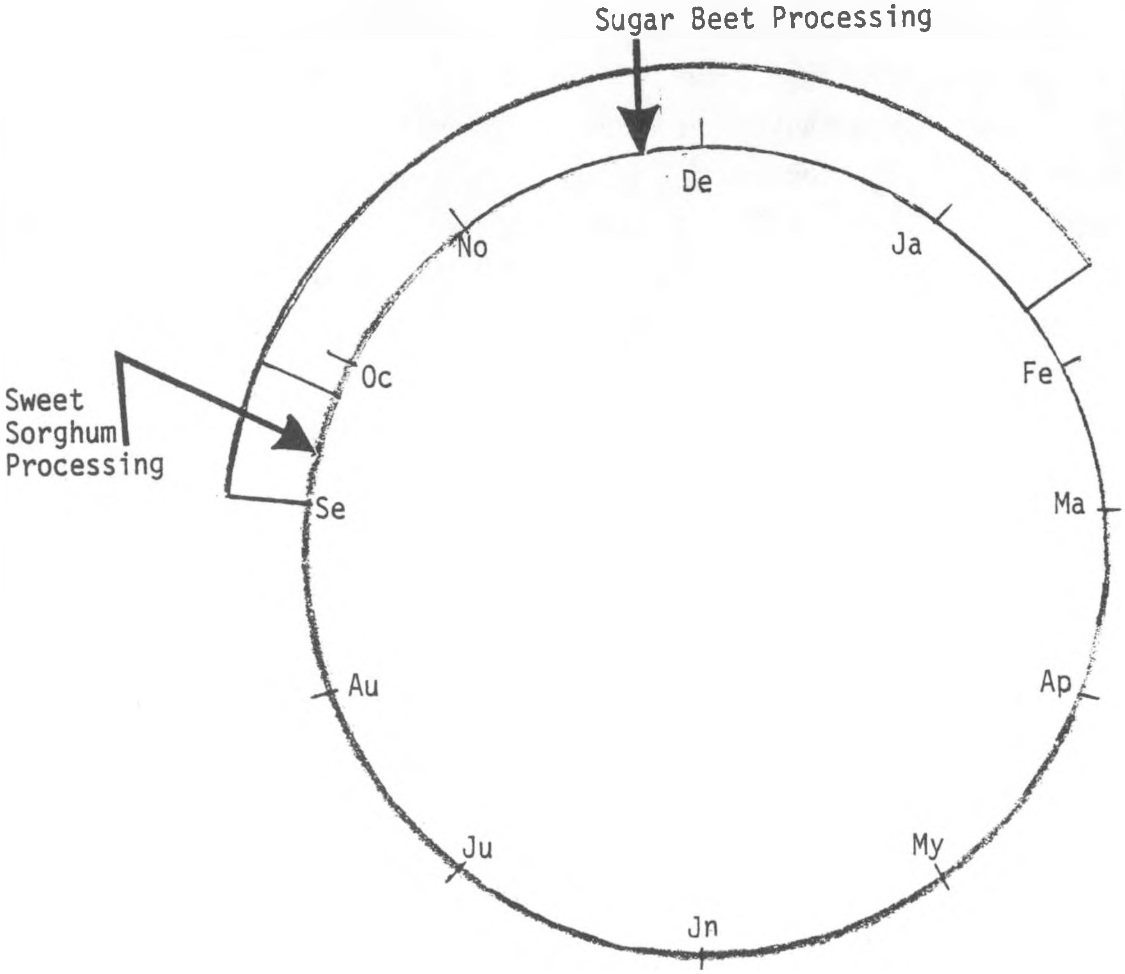

FIGURE 8. MOST LIKELY INTEGRATION ALTERNATIVES--NORTHWESTERN OHIO*

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* Normal (Sugar Beet) processing season is 110 days. Integrated processing season potentially 140 days.

*The California integration concept does not appear to interfere with existing agricultural practices. In fact, the addition of sweet sorghum and sugarcane appears to be logical given the very favorable climate, and the existing agricultural crops (red winter wheat, etc.) grown in the region. Nonetheless, because only limited experimental results are available for the growing of sweet sorghum and sugarcane in the Imperial Valley of California, only judgemental estimates can be made with regard to the actual timing of operations, the expected costs of production, and the anticipated yields.

The addition of sweet sorghum agriculture to the Louisiana sugarcane growing area appears to be a viable concept from production and processing technical viewpoints. Also, more detailed experimental data is available for Louisiana sweet sorghum agriculture allowing better estimates to be made of yields and production costs. Sugarcane production in Louisiana typically operates on a four year rotation schedule. Year one (plant cane) represents the first crop after planting of the sugarcane stalk segments. Year two, called first stubble, is the second year of sugarcane in the rotation. Year three, or second stubble, is the last year most growers grow sugarcane on the same acreage in the rotation. The fourth year is a fallow period wherein the land is either left uncovered or planted into a grass or legume. In the central sugarcane area of Louisiana about 25 percent of the land lies fallow each year. Fallow lands are prepared for the plant cane crop between the third week in August and the first week in October. Therefore, if sweet sorghum is to be added to agricultural operations in the sugarcane area of Louisiana, sweet sorghum probably would have to be planted no later than April 15th in a staggered schedule, with harvesting beginning early to mid-August. This would allow enough time for fallow lands to be prepared for sugarcane acreage. In the Louisiana area, no major problems are anticipated regarding the timing of the processing operations as long as the previously mentioned commitments to the agricultural schedule are met.

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* Base crop refers to the existing crop processed in the location (e.g., sugarcane in Louisiana). Supplemental crop refers to the crop added to the integration system (e.g., sweet sorghum in Louisiana).

The assumed 140-day Ohio integration system of sugar beets and sweet sorghum appear to present no particular problems with regard to timing of agricultural operations. Sugar beets typically are processed between the third week in October and the third week in January, or a 120-day processing season. Fermentable sugars from sweet sorghum, given the existing cultivars, and climate in Northern Ohio, would indicate that fermentable sugars could be available from sweet sorghum from September 1 through the third week in September.

In summary, several comments can be made with regard to implications of the integration concepts:

- Extension of the processing season through integration in all three geographic areas should fit reasonably well with timing of existing agricultural operations. The processing season would be extended 233% in California (300/90), 22% in Louisiana (110/90), and 27% in Ohio (140/110). All other things being equal, extension of the processing season by the above amounts would reduce overhead costs by 1 minus the inverse of the processing season extension (e.g., 1-[1/(300/90)] = 0.70.
- Raw material availability for extension of the processing season can be assured in two key ways. First, the assured availability of raw material for extension of the season can be enhanced by thoroughly investigating potential timing problems with regard to agricultural processing operations. Second, profit potential perception for both growers and processors should be adequate to encourage raw material availability. Also, purchase of raw material can be handled in a number of different ways, including open market purchases, contractual arrangements, etc.
- The major advantage of the three integration systems selected is that they are all sugar crop-based. It has been estimated that at least 80% of the investment in sugar crop fermentation is within the front end of the sugar crop handling and juice processing equipment. Therefore, with this equipment in place under the existing system, minimal investment would be required for fermentation to alcohol. Also, sugar crop fermentation also is a disadvantage in that by-product stillage disposal remains a potential environmental problem. The problem of disposal of the high salts-containing sugar crop stillage would be most serious in California where soils already are quite saline. Disposal of sugar crop stillage in Louisiana and Ohio soils also is a problem, but probably less severe than in California.

CONCEPTUAL MODELS

The three integration models are based on a number of assumptions. These assumptions are listed in Table 5, and discussed below.

Assumptions

For the analysis, in each geographical location the extension of the processing season was assumed to be limited by the agricultural and processing timing of operations. Therefore, the length in days of the extension of the processing season varies depending upon location. In California, typical sugar beet fermentable sugars would be available over a 90 day period. The timing of agricultural and processing operations allows an extension to the season of an additional 210 days. In Louisiana, extension of the processing season beyond typical sugarcane processing season only is 20 days, while in Ohio the extension period is 30 days.

The quantity of raw material able to be processed per day is based on the capacity of the representative facility used in the analysis. It was assumed (because of contradictory information regarding diffusor capacities) for the sugar beet facilities in California and Ohio that 65 percent of the beet processing capacity could be used for the stalk crops sugarcane and sweet sorghum. It was assumed that sweet sorghum, however, could be processed in sugarcane mills at full capacity.

Two cases were examined regarding the origin of fermentable sugars for manufacture of alcohol. It was assumed that alcohol could be manufactured from all crops in the integration system (that is, the base crop plus the supplemental crop(s), or only the supplemental crop.

Sugar-containing juices would be concentrated to a 70 percent solution when the juices could not be fermented immediately because of timing problems associated with the base crop processing season. There

TABLE 5. CONCEPTUAL MODEL ASSUMPTIONS

- Extension of processing season limited by agricultural and processing timing of operations. The length (days) of processing varies by geographic location.
- Quantity of raw material able to be processed per day based on the size of the representative plant facility. Assumed (because of contradictory diffusor information) that for sugar beet plants (CA and OH) only 65%of beet processing capacity could be used for stalk crops. It was assumed that sweet sorghum could be processed in sugarcane mills at the same normal capacity.
- Alcohol could be manufactured from all crops in the integration system (i.e. the base crop plus the supplemental crop(s)), or only the supplemental crop(s). Both cases are presented.
- Sugar-containing juices would be concentrated to a 70% solution when the juices cannot be fermented immediately.
- Overhead costs under an integrated system reduced by 1 minus the inverse of the increase in length of season, after any increase in depreciable equipment.
- No credits are taken for by-products (fiber) or for the federal and state excise tax exemptions. Likewise no costs were attributed to disposal of the sugar crop stillage.

is a trade-off between the energy costs associated with concentration of sugar juices plus the associated storage equipment investment, and the investment in a large (oversized) alcohol production facility. Because the sugar extraction and concentration equipment already are in place at both sugar beet and sugarcane processing facilities, it was assumed that sugar juices would be concentrated (requiring a storage equipment investment), rather than building a very large alcohol production facility that could process sugar-containing juices immediately upon extraction. Therefore, while extraction and concentration of juices occurs over a relatively short period of time, the alcohol production period is spread over the year excluding the time required for base and supplemental crop processing.

Overhead costs associated with the base facility under the integration system were assumed to be reduced by the inverse of the proportional increase in length of the season.

No credits were taken for by-products resulting from the fermentation of the sugar crops (e.g., fiber), or for the federal (and where appropriate, state) excise tax exemptions. Likewise, no costs were attributed to disposal of the sugar crop stillage. A more detailed, site specific study should address these factors; however they should not affect the results of this conceptual study.

PRODUCTION AND PROCESSING COSTS

For the assumed integration systems, agricultural production costs and processing costs for the base crops have been estimated. Agricultural production costs provide the basis for the raw material input costs for the ethanol fermentation system. Processing costs were estimated to determine the savings to companies in overhead costs from extension of the processing season.

Production Costs

Production costs for the three crops in the three locations were estimated based on FEDS data*, Battelle estimates, and experimental results from processors who have grown the crops in their location. Typically, production costs are broken into three major components: variable costs; fixed costs (including land, depreciation, taxes, etc.); and a management charge (usually 7% of estimated gross receipts). Total variable, fixed, and management charge costs would represent full costs to the grower, and generally would provide an adequate return on investment for farmers over the long run. Therefore, Battelle has taken total costs and divided by the estimated yield per acre to determine the processors purchase costs for raw material.

Table 6 indicates estimated crop yields, and production costs for the integrated system. Crop yields per acre are estimated both in terms of tons of biomass and tons of fermentable sugars. These yields are converted to production cost per ton of both biomass and fermentable sugars based on the estimated total production costs discussed above. Costs of fermentable sugars across the three locations range from a low of $0.033 to a high of $0.096 per pound. Assuming 14.28 pounds of fermentable sugars per gallon of ethanol, raw material ethanol costs would range from $0.47 to $1.37 per gallon. Raw material costs under the integrated alcohol production system are based on the weighted average unit cost of fermentable sugars given the amount of each crop utilized in the process.

Raw Material and Processing Costs

Raw material and processing costs for the three locations prior to integration are illustrated in Figures 9 through 11. Total costs for California sugar beets are $50.73 per ton. This estimated cost for California is slightly higher than that of Ohio's $49.10 per ton. Pre-integration raw material and processing costs for the Louisiana sugarcane mills are estimated at $28.59 per ton.

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* FEDS refers to Firm Enterprise Data System crop production budgets published by the U.S. Department of Agriculture and Oklahoma State University.

TABLE 6. ESTIMATED CROP YIELDS, AND PRODUCTION COSTS FOR INTEGRATION SYSTEMS.

	Crop Yield	Ferm. Sugar Yield	Prod. Cost	Prod. Cost[a]	Cost Ferm. Sugar	
	tons/acre	tons/acre	$/acre	$/ton	$/ton	$/Lb.
California, Imperial Valley						
Sugar Beets	26.0	4.0 (15.4%)	$770	$29.61	$192.50	$0.096
Sugarcane	30.0	4.8 (16.0%)	770	25.67	160.42	0.080
Sweet Sorghum	20.0	3.0 (15.0%)	395	19.75	131.68	0.066
Louisiana						
Sugarcane	22.1	3.1 (14.0%)	411	18.60	132.58	0.066
Sweet Sorghum	32.0	3.1 (14.7%)	310	9.69	65.96	0.033
Ohio						
Sugar Beets	21.0	3.4 (16.2%)	580	27.62	170.58	0.085
Sweet Sorghum	22.5	2.5 (11.1%)	287	12.76	114.80	0.057

(a) Excludes processing plant front-end handling of raw material.

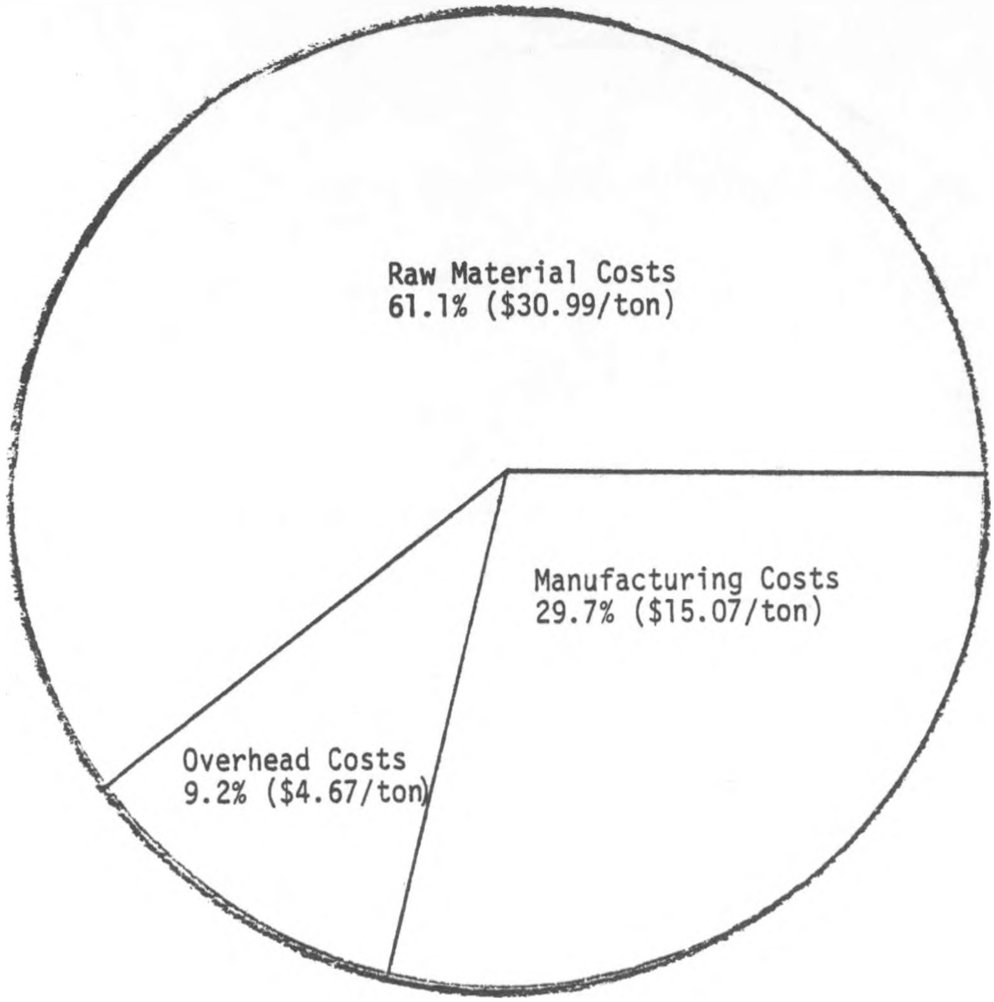

FIGURE 9. PRE-INTEGRATION COSTS--
IMPERIAL VALLEY, CALIFORNIA SUGAR BEETS

TOTAL RAW MATERIAL AND PROCESSING COSTS = $50.73/TON SUGAR BEETS

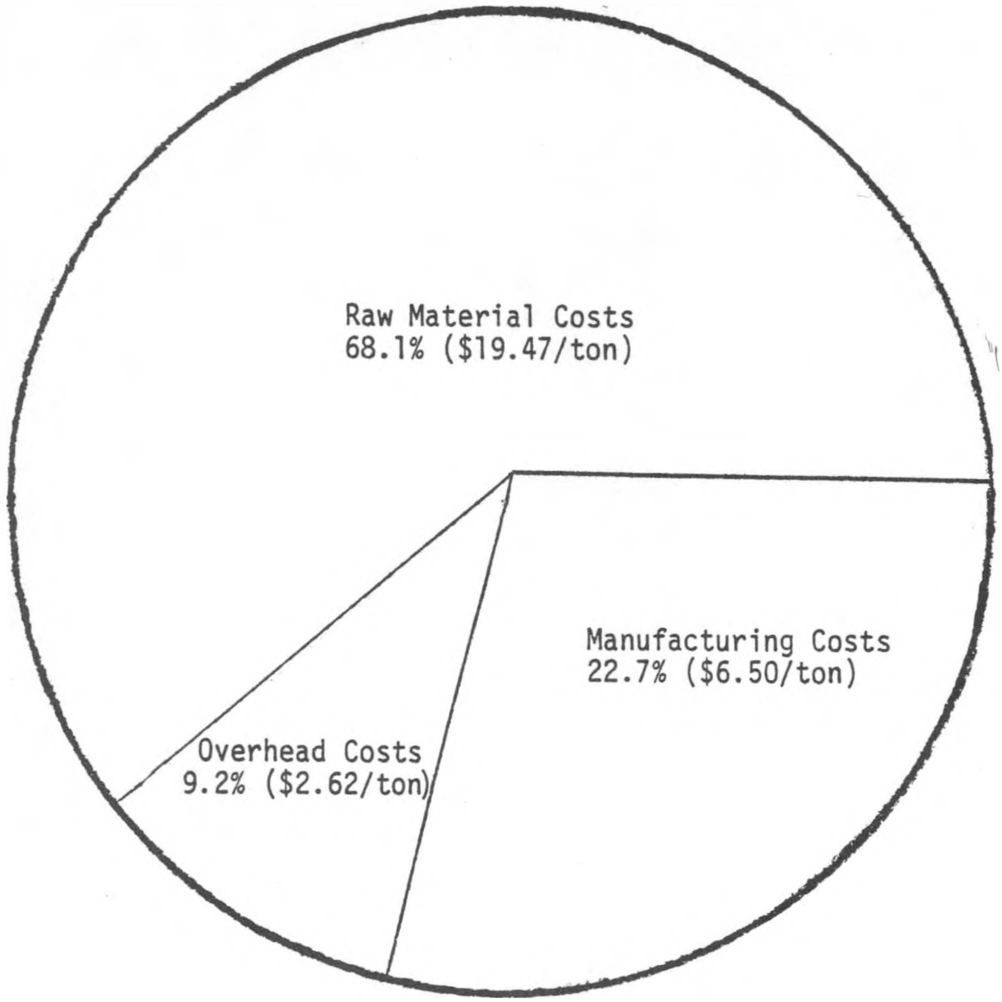

FIGURE 10. PRE-INTEGRATION PROCESSING COSTS--
LOUISIANA SUGARCANE

TOTAL RAW MATERIAL AND PROCESSING COSTS = $28.59/TON SUGARCANE

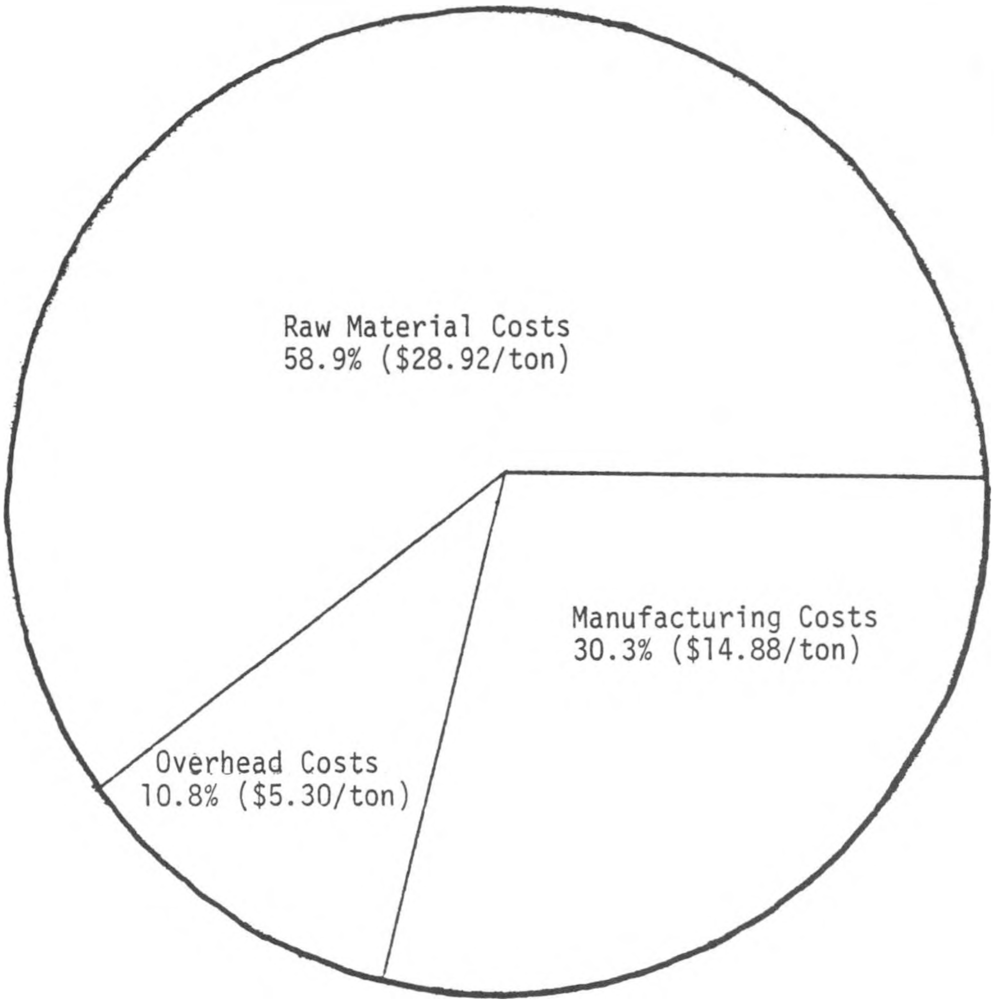

FIGURE 11. PRE-INTEGRATION PROCESSING COSTS, NORTHWESTERN OHIO

TOTAL RAW MATERIAL AND PROCESSING COSTS = $49.10/TON SUGAR BEETS

Typically, raw materials costs for agricultural crop processing range from 55 to 70 percent of total unit costs. Manufacturing costs typically range from 20 to 35 percent and overhead costs range from 5 to 15 percent. These typical ranges in cost inputs appear to hold well for the sugar beet and sugarcane processing systems. Under an integrated system, the raw material and manufacturing costs should not change significantly from the base crop estimates. However, overhead costs should be reduced by the proportional increase in season length, as the fixed cost can be spread over more units. Overhead (fixed) costs per ton of raw material for California, Louisiana, and Ohio, respectively, were estimated at $4.67, $2.62, and $5.30.

The Integration Systems

The quantities of sugar crops able to be processed over the season are summarized in Table 7, and presented in more detail in the three following tables, 8 through 10. As stated earlier, while there are three basic integrational alternatives, each alternative has two options. The first option under the integration system is that both the base and supplemental crops would be used for ethanol production. This option is called full integration. The second option is that only the supplemental crop would be used for production of alcohol, while the base crop would be used for the production of table sugar. This option is termed partial integration.

Given the quantities of raw material able to be processed over the season length, the weighted average costs of raw material (the fermentable sugars) can be calculated based on the production costs shown earlier in Table 6. The weighted average costs of fermentable sugars range from a low of $0.061 per pound for the partial integration (sweet sorghum only) in Louisiana to a high of $0.142 per pound for the full integration system (sugar beets and sweet sorghum) in Ohio (Table 11). Using 14.28 pounds of fermentable sugars per gallon of ethanol is equivalent to a raw material ethanol cost ranging from $0.87 per gallon to $2.03 per gallon.

TABLE 7. ESTIMATED QUANTITIES OF SUGAR CROPS ABLE TO BE PROCESSED

	Sugar Beets	Sweet Sorghum	Sugarcane	Total
		1,000 Tons		
CALIFORNIA				
Over 90 days	567.0	-	369.0	1,428.0 over 120 days
Over 120 days	-	492.0	-	
LOUISIANA				
Over 90 days	-	-	459.0	545.7 over 110 days
Over 20 days	-	86.7	-	
OHIO				
Over 110 days	500.5	-	-	589.3 over 140 days
Over 30 days	-	88.8	-	

TABLE 8. CONCEPTUAL MODELS: CALIFORNIA PROCESSING

	Process Tons/Day Beets/Stalks	Process Tons/Day Ferm Sugars	Days Processing	Total Tons Beets/Stalks	Total Tons Ferm Sugars	% of Total Beets/Stalks	% of Total Ferm Sugars
Sugar Beets [a]	6,300	977	90	567,000	87,930	39.7%	39.6%
Sugarcane [b]	4,100 [d]	656	120	492,000	78,720	34.5	35.5
Sweet Sorghum [c]	4,100 [d]	615	90	369,000	55,350	25.8	24.9
Totals			300	1,428,000	222,000	100.0%	100.0%

a) At 15.4% Ferm Sugar
b) At 16.0% " "
c) At 15.0% " "
d) 65% of Sugar Beet Processing Capacity

TABLE 9. CONCEPTUAL MODEL:
LOUISIANA PROCESSING

	Tons/Day		Days	Total Tons		% of Total	
	Beets/Stalks	Ferm Sugars	Processing	Beets/Stalks	Ferm Sugars	Beets/Stalks	Ferm Sugars
Sugar Cane [a)]	5,100	714	90	459,000	64,260	84.1%	83.5%
Sweet Sorghum [b)]	4,335	637	20	86,700	12,744	15.9	16.5
Totals			110	545,700	77,004	100.0%	100.0%

a) At 14.0% Ferm Sugar
b) At 14.7% Ferm Sugar

TABLE 10. CONCEPTUAL MODEL: NORTHWEST OHIO PROCESSING.

	Tons/Day		Days	Total		% of Total	
	Beets/Stalks	Ferm Sugar	Processing	Beets/Stalks	Ferm Sugars	Beets/Stalks	Ferm Sugars
Sugar Beets [a)]	4,550	737	110	500,500	81,081	84.9%	89.2%
Sweet Sorghum [b)]	2,960 [c)]	329	30	88,800	9,857	15.1	10.8
Totals			140	589,300	90,938	100.0%	100.0%

a) At 16.2% Ferm Sugar
b) At 11.1% " "
c) 65% of beet processing capacity

TABLE 11. CONCEPTUAL MODELS: ETHANOL RAW MATERIAL COSTS (ESTIMATED)

	Weighted Average Cost of Raw Material (Fermentable Sugars) ($/lb)	Raw Material Ethanol Cost a) ($/lb)	Equivalent Raw Material Ethanol Costs From Corn ($/lb)
CALIFORNIA			
Full (SB/SS/SC)	$ 0.083	$ 1.18	$ 3.07
Partial (SS/SC Only)	0.074	1.06	2.76
LOUISIANA			
Full (SC/SS)	0.092	1.31	3.41
Partial (SS Only)	0.061	0.87	2.26
OHIO			
Full (SB/SS)	0.142	2.03	5.28
Partial (SS Only)	0.138	1.97	5.12

a.) At 14.28 lbs Ferm Sugars/Gallon Ethanol

As a means of comparison, the equivalent raw material ethanol costs from corn have been calculated. If corn were used as the raw material, the equivalent raw material cost would range from a low of $2.26 per bushel to a high of $5.28 per bushel. The current (November, 1980) Chicago cash price for corn is about $3.50 per bushel.

Using the quantities of raw materials able to be processed through this integration system, estimated quantities of ethanol able to be produced can be calculated. Table 12 indicates the approximate number of gallons per year able to be produced under varying lengths of processing season. The range in alcohol production is quite large at 1.4 to 30.9 million gallons per year. Gallons of ethanol per day production capacities also are noted in Table 12 along with the approximate equivalent alcohol facility size based on a 330-day year. The equivalent facility size given the number of days of operation per year is larger in four of the six cases, than the approximate gallonage able to be produced given the quantities of raw material processed. As such, unless additional sugar crops or grains could be processed and fermented, the alcohol plant will not be used to its full capacity.

Because the crop processing seasons are short and the fermentable sugars extremely perishable, the fermentable sugars that are available but cannot be fermented immediately due to ongoing processing (and the resulting unavailability of steam generation, etc.) need to be concentrated and stored. Sugar syrup concentration should be at least 70 percent sugar. Table 13 calculates the number of gallons of sugar syrup storage required assuming 25 gallons of sugar syrup per ton of crop. Additional comments regarding the storage capacity calculations can be found in footnote b of Table 13. Briefly, it was assumed that the yield of 25 gallons of syrup of ton of stalks or beets would be held constant, but the degree of concentration would vary, but always over at least 70%.

TABLE 12. ESTIMATED QUANTITIES OF ETHANOL ABLE TO BE PRODUCED.

	Approximate MM Gals./Yr.	Approximate Gals./Day	Equivalent Alcohol Facility Size MM Gals./330 Day Yr.
California			
Full (SB/SC/SS)	30.9	93,600 [a)]	30.9
Partial (SC/SS)	18.8	57,000 [a)]	18.8
Louisiana			
Full (SC/SS)	10.8	49,000 [b)]	16.2
Partial (SS)	1.8	8,100 [b)]	2.7
Ohio			
Full (SB/SS)	12.7	60,500 [c)]	20.0
Partial (SS)	1.4	6,700	2.2

a) At 330 Days Fermentation/Yr.
b) At 220 Days Fermentation/Yr.
c) At 210 Days Fermentation/Yr.

TABLE 13. ESTIMATED CONCENTRATED SUGAR SOLUTION STORAGE CAPACITY REQUIREMENTS(a)

	Processing Season Length	Fermentation Season Length	Ethanol Produced Over Processing Season	Necessary Storage Capacity Required
	—Days—	—Days—	—MM Gals—	—MM Gals—
CALIFORNIA				
Full (SB/SC/SS)	300	330	28.2	3.2
Partial (SC/SS)	210	330	12.0	7.8
LOUISIANA				
Full (SC/SS)	110	220	0	13.6
Partial (SS)	20	220	0	2.2
OHIO				
Full (SB/SS)	120	210	0	14.7
Partial (SS)	30	210	0	2.2

a) Assumes varying concentrations of sugar solutions of over 70%, but at a yield of 25 gallons concentrated sugar syrup per ton of raw material processed.

b) Calculated by dividing 25 (per footnote a) by the number of gallons ethanol able to be produced per ton of raw material as based on the weighted average fermentable sugar content. This equation indicates the number of gallons syrup required per gallon of ethanol. The ethanol gallonage not produced over the processing season then was divided by gallons syrup per gallon of ethanol to give gallons syrup storage required.

ETHANOL COSTS

Ethanol costs were calculated for the three integration alternatives, and the two options for each alternative. Ethanol costs are based on several options as noted below:

- Capital investments based on a 40% equity/60% debt balance
- Depreciation on capital investments based on an 18-year straight line schedule
- Interest on debt averaged over a ten-year loan mortgage at 15%
- Return on equity was based on a before-tax 20% rate

Ethanol Production Capital Investment

Capital investment for the ethanol facilities was calculated and scaled down from FC Schaeffer's 1978 estimates which had been inflated by 20% to 1980 prices.* Appropriate equipment costs were scaled down using a 0.6 power factor for all but the two smallest facilities of 1.4 and 1.8 million gallons per year. For the two smallest facilities, a more liberal 0.5 power factor was used. The capital investment charges are believed to be +50; -30% accurate.

Because of the already-in-place raw material processing equipment at the three locations, only for the two California options was steam and electric power generation equipment required. In all of the cases, given the schedule of processing and fermentation-distillation operations, only the fermentation and distillation equipment was required. Investment and concentrated sugar syrup's storage facilities were added in all cases to other capital equipment charges.

Capital investment in the integration system ranges from a high of 30.8 million dollars for the full integration California system to a low of $2 million for the Ohio partial integration system.

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* See E.S. Lipinsky, et. al., Sugar Crops As A Source Of Fuels: "Volume II: Processing and Conversion Research" to US DOE, Battelle Columbus Division, August 31, 1978. F.C. Schaeffer's 1978 estimates for production and investment expenses associated with the production of ethanol from sugarcane are shown in Appendix A.

Capital costs, equity and debt balances, and the basis for calculating costs for anhydrous ethanol production are noted in Tables 14 through 19.

Ethanol Production Costs

The costs of the raw material fermentable sugars were calculated earlier in Table 11, and transferred to Tables 14 through 19. Operating costs for salaries, repairs, and insurance etc., (excluding fuel) were assumed to be $0.19 under all integration options. Fuel costs were based on the availability of fiber for fuel, and the est-estimated number of Btu's required for fermentation and distillation, at a $4 per million Btu charge. It was conservatively believed that adequate fiber from sugarcane and sweet sorghum raw materials would be available for concentration of sugar syrups and subsequent heating of the sugar syrups just prior to fermentation. Fuel was assumed to be purchased as needed for fermentation and distillation.

Summary of Ethanol Costs

Estimated capital investment costs in dollars per gallon of annual output range from a low of $0.68 for the Ohio full integration option to a high of $1.61 for the Louisiana partial integration option, (Table 20). The estimated production costs for anhydrous ethanol range from a low of $1.57 per gallon for the Louisiana partial integration option to a high of $2.75 for the full Ohio integration option. Typically, ethanol facility investment costs, as measured by dollars of investment per million gallons of annual output, decrease as the facility size increases. As shown in Tables 14 through 20, investment costs under the six integration systems bear little, if any, relation to annual output of ethanol. This is due principally to the significant amount of already in-place equipment (especially boilers) at the sugarcane and sugar beet facilities able to be used for ethanol production. Also, it is typical for ethanol production costs to bear a high degree of relationship to the per million

TABLE 14. PROJECTED COST OF ANHYDROUS ETHANOL
CASE A: CALIFORNIA FULL INTEGRATION,
ALCOHOL FROM SB/SC/SS, NO SUGAR PRODUCED

CAPITAL COST			$30,800,000
Initial Equity			$12,320,000 (40%)
Initial Debt			$18,480,000 (60%)
Basis:	Length of Fermentation Period, Days		330
	Total Alcohol Produced, Gallons Per Year		30,900,000
	Alcohol Produced, Per Day		93,600
	10 Year Annual Average		

	$/Gallon Anhydrous	Annual $
PRODUCTION COSTS		
(Fermentable Sugars	$ 1.18	$36,462,000
Other Operating Costs (Salaries, Fuel, Repairs, Insurance, Etc.)	0.49	15,141,000
Subtotal	$ 1.67	$51,603,000
DEPRECIATION AND INTEREST		
Depreciation, 18 year straight line	$ 0.06	$ 1,854,000
Interest @ 15%	0.06	1,854,000
Subtotal	$ 0.12	$ 3,708,000
RETURN ON EQUITY		
ROE @ 20% Before Taxes	$ 0.08	$ 2,472,000
TOTAL COSTS	$ 1.87	$57,783,000

TABLE 15. PROJECTED COST OF ANHYDROUS ETHANOL
CASE B: CALIFORNIA PARTIAL INTEGRATION,
ALCOHOL FROM SC/SS, SUGAR FROM SB

CAPITAL COST		$23,900,000
Initial Equity		$ 9,560,000 (40%)
Initial Debt		$14,340,000 (60%)
Basis: Length of Fermentation Period, Days		330
Total Alcohol Produced, Gallons Per Year		18,800,000
Alcohol Produced, Per Day		57,000
10 Year Annual Average		
	$/Gallon Anhydrous	Annual $
PRODUCTION COSTS		
(Fermentable Sugars	$ 1.06	$19,928,000
Other Operating Costs (Salaries, Fuel, Repairs, Insurance, Etc.)	0.39	7,332,000
Subtotal	$ 1.45	$27,260,000
DEPRECIATION AND INTEREST		
Depreciation, 18 year straight line	$ 0.07	$ 1,316,000
Interest @ 9%	0.07	1,316,000
Subtotal	$ 0.14	$ 2,632,000
RETURN ON EQUITY		
ROE @ 20% Before Taxes	$ 0.10	$ 1,880,000
TOTAL COSTS	$ 1.69	$31,772,000

TABLE 16. PROJECTED COST OF ANHYDROUS ETHANOL
CASE C: LOUISIANA FULL INTEGRATION,
ALCOHOL FROM SC/SS, NO SUGAR PRODUCED

CAPITAL COST			$ 8,000,000
Initial Equity			$ 3,200,000
Initial Debt			$ 4,800,000
Basis:	Length of Fermentation Period, Days		220
	Total Alcohol Produced, Gallons Per Year		10,800,000
	Total Alcohol Produced, Gallons Per Year 10 Year Annual Average		49,100
		$/Gallon Anhydrous	Annual $
PRODUCTION COSTS			
(Fermentable Sugars		$ 1.31	$14,148,000
Other Operating Costs (Salaries, Fuel, Repairs, Insurance, Etc.)		0.39	4,212,000
	Subtotal	$ 1.70	$18,360,000
DEPRECIATION AND INTEREST			
Depreciation, 18 year straight line		$ 0.04	432,000
Interest @ 9%		0.04	432,000
	Subtotal	$ 0.08	$ 864,000
RETURN ON EQUITY			
ROE @ 20% Before Taxes		$ 0.06	$ 648,000
TOTAL COSTS		$ 1.84	$19,872,000

TABLE 17. PROJECTED COST OF ANHYDROUS ETHANOL
CASE D: LOUISIANA PARTIAL INTEGRATION,
ALCOHOL FROM SS, SUGAR FROM SUGARCANE

CAPITAL COST		$ 2,900,000
Initial Equity		$ 1,160,000
Initial Debt		$ 1,740,000
Basis: Length of Fermentation Period, Days		220
Total Alcohol Produced, Gallons Per Year		1,800,000
Alcohol Produced, Per Day		8,200
10 Year Annual Average		
	$/Gallon Anhydrous	Annual $
PRODUCTION COSTS		
(Fermentable Sugars	$ 0.87	$ 1,566,000
Other Operating Costs (Salaries, Fuel, Repairs, Insurance, Etc.)	0.39	702,000
Subtotal	$ 1.26	$ 2,268,000
DEPRECIATION AND INTEREST		
Depreciation, 18 year straight line	$ 0.09	$ 162,000
Interest @ 9%	0.09	162,000
Subtotal	$ 0.18	$ 324,000
RETURN ON EQUITY		
ROE @ 20% Before Taxes	$ 0.13	$ 234,000
TOTAL COSTS	$ 1.57	$ 2,826,000

TABLE 18. PROJECTED COST OF ANHYDROUS ETHANOL
CASE E: OHIO FULL INTEGRATION,
ALCOHOL FROM SB/SS, NO SUGAR PRODUCED

APITAL COST			$ 8,700,000
Initial Equity			$ 3,480,000
Initial Debt			$ 5,220,000
asis:	Length of Fermentation Period, Days		210
	Total Alcohol Produced, Gallons Per Year		12,700,000
	Alcohol Produced, Per Day		60,500
	10 Year Annual Average		
		$/Gallon Anhydrous	Annual $
RODUCTION COSTS			
(Fermentable Sugars		$ 2.03	$ 25,781,000
Other Operating Costs (Salaries, Fuel, Repairs, Insurance, Etc.)		0.59	7,493,000
	Subtotal	$ 2.62	$ 33,274,000
EPRECIATION AND INTEREST			
Depreciation, 18 year straight line		$ 0.04	$ 508,000
Interest @ 9%		0.04	508,000
	Subtotal	$ 0.08	$ 1,016,000
ETURN ON EQUITY			
ROE @ 20% Before Taxes		$ 0.05	$ 635,000
OTAL COSTS		$ 2.75	$ 34,925,000

TABLE 19. PROJECTED COST OF ANHYDROUS ETHANOL
CASE F: OHIO PARTIAL INTEGRATION,
ALCOHOL FROM SS, SUGAR FROM SB

CAPITAL COST		$ 2,000,000
Initial Equity		$ 800,000
Initial Debt		$ 1,200,000
Basis: Length of Fermentation Period, Days		210
Total Alcohol Produced, Gallons Per Year		1,400,000
Alcohol Produced, Per Day		6,700
10 Year Annual Average		
	$/Gallon Anhydrous	Annual $
PRODUCTION COSTS		
(Fermentable Sugars	$ 1.97	$ 2,758,000
Other Operating Costs (Salaries, Fuel, Repairs, Insurance, Etc.)	0.39	546,000
Subtotal	$ 2.36	$ 3,304,000
DEPRECIATION AND INTEREST		
Depreciation, 18 year straight line	$ 0.08	$ 112,000
Interest @ 9%	0.08	112,000
Subtotal	$ 0.16	$ 224,000
RETURN ON EQUITY		
ROE @ 20% Before Taxes	$ 0.11	$ 154,000
TOTAL COSTS	$ 2.63	$ 3,682,000

TABLE 20. SUMMARY OF ESTIMATED CAPITAL AND PRODUCTION COSTS FOR ETHANOL INTEGRATION SYSTEMS[a]

	Estimated Capital Costs $/Gal. Annual Output	Estimated Production Costs $/Gal.
California		
Full (SB/SC/SS)	$1.00	$1.87
Partial (SC/SS)	$1.27	$1.69
Louisiana		
Full (SC/SS)	$0.74	$1.84
Partial (SS)	$1.61	$1.57
Ohio		
Full (SB/SS)	$0.68	$2.75
Partial (SS)	$1.43	$2.63

(a) From Tables 14 through 19.

gallon capital investment charges. Under the integration systems, as investment costs are less than they would be for a stand-alone ethanol facility, the ethanol production costs are much more closely tied to raw material costs. These two factors explain much of the seemingly contradictory statements that the Ohio full integration investment costs per million gallons ethanol output are the lowest of the six systems, yet the total ethanol production costs are the highest.

It should be noted that these estimated production costs for anhydrous ethanol exclude any credits for fiber or for federal excise tax exemptions. Nor do the estimated production costs include any charges or (credits) for the by-product sugar crop stillage.

Table 21 shows the estimated savings in fixed processing costs due to the integration systems. The overhead cost savings per ton of base crop processed was estimated to be \$3.27 per ton for the California system, \$0.47 for the Louisiana system, and \$1.17 for the Ohio system. These per unit overhead cost savings translate to annual savings of \$0.22 million in Louisiana, to a high of \$1.85 million in California. If these overhead cost savings for each facility were deducted from ethanol costs they would translate to a credit of \$0.02 to \$0.42 per gallon of ethanol produced. The last column in Table 21 indicates the net ethanol cost if the savings were deducted from final costs shown in Table 21.

With the possible exception of the Ohio integration systems, the ethanol costs would be competitive with the existing supply of ethanol from corn. This is especially true after deduction of the federal and possibly state excise taxes. As such, it would be helpful to estimate the potential ethanol production nationally, if integration was adopted on a larger scale.

TABLE 21. ESTIMATED SAVINGS IN FIXED PROCESSING COSTS DUE TO INTEGRATION

	Overhead Cost Reduction Factor[a]	Overhead Cost Savings Per Unit Per Ton[b]	Total Overhead Cost Savings for Facility		Net Ethanol Cost if Savings Deducted $/Gal.[e]
			$MM/Yr.(c)	$/Gal. E+OH(d)	
California					
Full (SB/SC/SS)	$0.30	$3.27	$1.85	$0.06	$1.81
Partial (SC/SS)	0.30	3.27	1.85	0.10	1.59
Louisiana					
Full (SC/SS)	0.82	0.47	0.22	0.02	1.82
Partial (SS)	0.82	0.47	0.22	0.12	1.45
Ohio					
Full (SB/SS)	0.78	1.17	0.59	0.05	2.70
Partial (SS)	0.78	1.17	0.59	0.42	2.21

(a) Calculated by dividing 1 by the proportionate increase in days of processing season. For California, the equation would be 1 ÷ (300 days/90 days) = 0.30.

(b) Per ton of base crop processed. Savings calculated by multiplying 1 minus the cost reduction factor times pre-integration overhead costs (see Figures 11 through 13). For California: (1-0.30)($4.67) = $3.27.

(c) Savings per ton of base crop times number of tons of base crop processed.

(d) Total overhead savings divided by number of gallons ethanol produced under each integration option equals $/gallon ethanol savings.

(e) If _all_ savings were allocated to ethanol production. Savings per gallon ethanol subtracted from estimated ethanol production costs as shown in Table 20.

POTENTIAL ETHANOL PRODUCTION UNDER WIDE ADOPTION OF INTEGRATED SYSTEMS

It is extremely difficult to estimate potential ethanol production under wide scale integrated systems due to the high site specificity associated with the integration concept. However, given a selected set of assumptions, some estimates can be made of potential ethanol production. Assumptions might include:

- one-half of the number of facilities now processing sugarcane and sugar beet's go to an integrated system
- average daily processing capacity is 4,000 tons per day
- 14% average fermentable sugar content
- processing season is extended by 30 days

Under the above assumptions, some 35 facilities would be processing 4,000 tons of sugar crops per day for 30 days at 14% fermentable sugars. Such an integrated system nationally would produce some 588,000 tons of fermentable sugars annually, or at 140 gallons of ethanol per ton of fermentable sugars, some 80 million gallons of ethanol might be able to be produced.* In addition, approximately 17 sugar beet processing facilities that now are closed could potentially be converted to ethanol production facilities. Assuming 90 day seasons at 4,000 tons per day at 14% fermentable sugars, an additional 120 million gallons of alcohol might be able to be produced from these currently closed sugar beet facilities.

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* At 83,000 Btu's per gallon of ethanol, the production of 80 million gallons of ethanol would be the equivalent of 6.6×10^{12} Btu's.

EXECUTIVE SUMMARY

Systems Analysis Formulation for Estimating Impacts of Sweet Sorghum Production Upon United States Agriculture

The overall objective of this task was to initiate a systematic approach to be used by the Department of Energy for developing a forecast of prices and production of agricultural commodities that might be affected by a large scale alcohol production program. As part of the study, special consideration was to be given to carbohydrate crops such as sweet sorghum, that could be used for alcohol production.

The program included an extensive review of the literature and a listing of many models that were of assistance in formulating the Battelle model. Three models were reviewed extensively - econometric simulation models such as Polysim and Agrimod and two linear programming models. It was concluded that the best approach was to develop a linear programming model that combined the best attributes of the previous models.

The Battelle model is a supply model driven by exogenous demand variables such as protein, starch, and alcohol. The model was predicated on the need to bring new land into production to produce the required agricultural crops. The area under consideration for the study was the Corn Belt - the states of Illinois, Indiana, Iowa, Missouri and Ohio. Six crops were produced on the land. Corn, soybeans, winter wheat, grain sorghum, oats and alfalfa. Sweet sorghum was phased in as an energy crop and competed with the other crops for the land resources.

The model results indicated that from 1977 through 1985, nearly 10 million additional acres of cropland would be needed to produce the crops for required protein and starch demand as well as nearly 1 billion gallons of alcohol. Corn production would increase by 600 million bushels, while soybean production would remain relatively constant. Wheat production would increase by nearly 70 million bushels, nearly 24 percent while oats and alfalfa production would remain constant.

Grain sorghum production would increase nearly 19 million bushels or nearly 24 percent, while sweet sorghum production would increase from 0 to 12 million tons.

Crop prices would remain relatively constant in 1977 dollars for corn, soybeans, alfalfa, and grain sorghum. Wheat prices were estimated to increase about 23 percent, while oats prices were estimated to increase about 33 percent.

In Battelle's opinion, not all of the model results are realistic in terms of the anticipated changes in crop production and commodity prices. For example, it does not seem reasonable to expect that corn and grain sorghum prices would remain relatively constant while wheat and oat prices would increase significantly as a result of increased alcohol production. Also, it does not appear likely, from a technical standpoint, that large quantities of wheat acreage will be brought into production for alcohol as indicated by the model results. It is emphasized that the purpose of this task was to initiate development of an approach to forecasting the potential economic impact of integrating biomass for fuels production into the existing U.S. agricultural system. The model results indicate that, as expected, some of the assumptions and constraints in the Battelle model need to be re-examined. If the U.S. Department of Energy chooses to pursue this project further, additional testing of the model could be conducted to substantiate or refute some of the initial results.

The results indicate that it is possible to predict agricultural production and changes resulting from alcohol fuels programs utilizing agricultural crops. The model could be extended to include total production for the United States and take into consideration inter-regional transfers, and regional energy crops such as sugar beets, sweet sorghum, or sugarcane. It would be possible to use the model to derive supply curves that could be used to assess various policy options considered by the Department of Energy.

SYSTEMS ANALYSIS FORMULATION FOR ESTIMATING IMPACTS OF SWEET SORGHUM UPON UNITED STATES AGRICULTURE

Introduction

The production of alcohol from renewable resources and particularly carbohydrate crops has been cause for considerable discussion and controversy. Among those deeply concerned are individuals that regard using the farmland for production of fuel as a less than optimal and acceptable alternative when part of the world population consumes diets that are considered less than adequate. However, when one considers the President's objectives for a massive alcohol fuels program, one cannot help but think that such a program could have a substantial impact on U.S. agricultural food production systems.

Production of large volumes of alcohol from agricultural crops to displace 10 percent or even 5 percent of the current gasoline consumption would require millions of acres of land. Some of that land is idle and fallow; however other portions of the land are devoted to producing crops such as grains or oilseeds that have traditional uses as foods for humans or livestock. It has been argued that protein rich by-products from the production of alcohol (distillers dried grains) would supplement the existing feed grain supply and provide more than adequate protein for feeding of livestock. Corn, soybeans, and grain sorghum are the crops most likely to be affected by widespread alcohol production. One could easily hypothesize an increased demand for grain while a declining demand for oilseed products. Any significant changes in corn, soybean, or grain sorghum prices would impact production costs of beef, pork, and poultry products and probably significantly impact the retail prices of those products to consumers.

Red meat and poultry are the mainstay of the U.S. consumer diet and the prices of those products are highly visible to consumers, primarily as the result of weekly shopping trips to a supermarket. In addition, higher grain and oilseed prices also could impact U.S. agricultural exports.

These exports represent a source of substantial quantities of foreign exchange and are a primary reason why the U.S. balance of payments has not become severely distorted as the result of large oil imports.

The numerous questions hypothesized by the proposed alcohol fuels production program that primarily relies on carbohydrate crops such as corn and grain sorghum and sugar crops, such as sweet sorghum, necessitate considerably greater study by the Department of Energy (DOE). It would seem that a program that might ultimately result in a cost benefit analysis of the relationship of using food crops as a means of producing liquid motor fuel should be valuable in policymaking considerations. In addition, such an investigation would help DOE better understand the relationship between renewable resource production, domestic food production, and agricultural exports-and become input to policymaking considerations. In addition, such a program also could study the impacts on employment, capital investment, and tax revenues.

Already there is precedent to investigate the impact of alcohol fuels production on U.S. agriculture. Agricultural sector models have been developed by Purdue University and Texas A&M University. These models have examined the potential impacts of producing energy from agriculture at various assumed levels of energy production. Between the two models there were some similarities in general results; for example, grain prices increased as alcohol production increased. However, the magnitude of forecasted changes was significantly different between the two models, primarily because of differing underlying assumptions in the model specifications.

Because of the underlying problems with the two established agricultural sector models and the concern of the impact of the alcohol fuels program on U.S. agricultural production, Battelle investigated the applicability of models which utilize linear programming as well as other methodological approaches, such as dynamic simulation and input/output analysis, and assessed the usefulness of these approaches for conducting economic impact analyses of energy production. The primary emphasis of this analysis was to obtain a means of predicting the impact of sweet sorghum on energy production. This report summarizes Battelle's work conducted during the past ten months on agricultural sectoral models.

Objective and Scope

The overall objective of this research task was to initiate a systematic approach for use by DOE to develop forecasts of prices and production of agricultural commodities that could be affected by a large scale program to produce alcohol from sweet sorghum or other carbohydrate crops. To accomplish the objective the program was divided into a number of subobjectives:

(1) Review literature to determine the suitability of various methodological approaches for simulating economic impact on U.S. agriculture

(2) Identify the specific output desired from the analysis

(3) Identify the data requirements for the analysis

(4) Identify commodity linkages and relationships affected by widespread implementation of an alcohol production system based upon sweet sorghum or other carbohydrate crops

(5) Estimate future quantities and prices of selected commodities and of by-products impacted by alcohol production

(6) Identify implications of estimated future quantities and prices of agricultural products upon the cost of producing alcohol and livestock.

The scope of this investigation involved the review of numerous agricultural sector models, and it is not the intent of this program to develop a working agricultural system model. The integration of sweet sorghum production into the agricultural model system, as well as an analysis of specific causal relationships and important inputs and outputs, is the major focus of this effort.

Organization of the Report

The report has been organized to quickly provide the reader with the rationale and results of the study. The first part consists of a brief literature review. A more extensive review of the literature is contained in Appendix B. The second part of the report describes briefly the types of models that could be used in this study and the reasons for selecting the particular approach taken. Part three is an indepth discussion of the variables selected for the model. The fourth part discusses data requirements while the fifth part discusses the model operations.* Part six is a discussion and analysis of the results. The final part of the report discussion is possible model extensions.

Summary of Literature Review**

For many years, modeling of the American agricultural sector has provided a convenient tool for analysis. When considering biomass as a major resource for fuel production, it is necessary to assess the impact of using fiber and food crops in such areas as production, pricing and marketing of the agricultural sectors. In all, regardless of the mathematical, economical and statistical theories employed, historical data is the base for all projections or descriptions.

The most common types of models of the American agriculture are either econometric simulations or mathematical optimization models.

In this program, econometric simulation models reviewed were Polysim and Agrimod. A descriptive projection study by Wisner and Gidel also was included. Among the optimization models reviewed, all were of the linear programming (LP) type. LP models that were examined included the Texas A&M Models, the Purdue Model and a spatial agriculture programming model, "Adjustments in Crop and Livestock Production".

*Basic Data sources for the model are described in detail in Appendix C.

**A detailed review of the literature is contained in Appendix B.

Econometric Simulation Models

Polysim is a stepwise simulation which allows the tracing of changes of variables such as yield, cost, demand, etc. prompted by policy actions. Elasticities are used in this model to relate variables considered in one iteration to the variables of the next iteration. Major drawbacks of Polysim are the subjectivity underlying the determination of the numerous elasticities, and the lack of spatial consideration.

Agrimod is a highly complex simulation model made up of several submodels. Agrimod describes the American agricultural sector with more detail than most models, however, this very degree of complexity makes it difficult to isolate changes directly related to any particular phenomenon studied (such as farming for energy production).

Wisner and Gidel's study was a detailed description of the impact of the implementation of gasohol production in the U.S. The methodology used projections and estimates relying strictly on past data and, therefore, fails to capture the essence of anticipated or desired changes which will result from implementation of a gasohol program.

Linear Programming Models

Heady's spatial agriculture programming model, "Adjustment in Crop and Livestock Production", has the major advantage that considerations of interdependency for regions and for commodities are included. Even though it would be possible to use this model and delete some of the variables included, the data gathering effort would be an extremely lengthy process. In addition, Heady is now in the process of investigating the impact of alcohol production from biomass in Iowa and in the U.S. Using Heady's existing model would have ignored important improvements that Heady plans to incorporate in the model now being developed.

Two models developed at Texas A&M have used linear programming analysis to evaluate impacts of national policy programs implemented in the agricultural sector. Within the framework of one of the models, the effect of producing alcohol from crops endogenous to the model on other agricultural commodities, prices, and distribution was observed. The model is valuable because the technique used maximizes consumers and producers' surpluses which is consistent with an accepted economics theory of consumers and producers welfare maximization. The Texas A&M model has another advantage of looking at the entire U.S. agricultural sector which must be eventually considered when looking at alcohol production from agricultural crops. However, the model in its present form has major disadvantages in that it does not allow for variation in crop production and land use from one region to another. Additional land which could be brought into production in the U.S. also was not considered in this model, thereby introducing a possible bias toward over-utilizing prime cropland for the desired output. To use this model it would be necessary to rebuild production equations so variation in yield and other crop production factors could be taken into account. The land constraint also should be redefined to reflect the option of using non-cropland for crops which could be used for alcohol production.

The LP-based Purdue Model's objective was to assess the impact of a large scale program to produce alcohol from agricultural crops on the U.S. agricultural sector. The model's scope included U.S. agriculture, as well as export and import provisions which corresponds well with the scope of Battelle's study. The agricultural commodities included in the Purdue model are those that most likely would be affected by an alcohol program. Some of the primary crop commodities included in the Purdue Model are used directly for alcohol fuel production (e.g., corn, sugarcane, sugarbeets, sorghum). Battelle, therefore, believed that the Purdue model represented the most advantageous basis for developing a modified model. However, several disadvantages of the Purdue model were evident when Battelle started to analyze the model in detail. Data limitations prevented the use of an uniform base year; therefore, a new data base would have had to be identified and data gathered for the most recent year available. The fact that the Purdue model looked at the entire U.S. agricultural sector was also a comparative disadvantage since Battelle's scope included only the Corn Belt Region at this initial stage of model development. Because of these reasons, Battelle opted to develop its own model.

Model Considerations

The policy implications of introducing sweet sorghum production into the agricultural sector may be best analyzed using a mathematical model. Such a model would provide consistent estimates of the market responses to assumed exogenous factors, and simulate future estimates as the factors change.

The problem is to determine what production changes and price increases will occur for various crops when a new crop, sweet sorghum, begins to compete for land resources. This problem is complicated because alcohol production from traditional crops such as corn and grain sorghum will increase demand for these two crops simultaneously. During the 1980's one could expect further demand increases for agricultural products as population increases gradually. As the demand changes occur, the market responses for supplying adequate amounts of protein, starch and alcohol could be estimated using the mathematical model.

The primary strength of using a mathematical model is that any number of different demand schedule scenarios can be analyzed for supply responses. The exact parameters of the schedule changes may be determined from a number of energy policy scenarios. In addition, a mathematical model is capable of solving problems concerning many production constraints, a task that would be difficult to estimate using a qualitative analysis framework.

A mathematical model is often thought of as a method for estimating reality. Over a historical time period, a model should come close to estimating a real situation. Over the forecast period the simulations should be both plausible and refined; however, it is important to remember that simulations may be best thought of as "changes". That is, the model results can be best analyzed by observing relative changes in the variables over the forecast period. For example, a forecasted five percent increase in potash requirements over a two-year period would be a more meaningful result than an actual estimate of potash requirements for the second year. Using the results of a model in this way reduces biases that may result from discrepancies between the model estimates and known reality in an historical year.

Any mathematical model will not exactly reproduce reality because all variables are not totally predictable. Individual farmers may not plant and produce optimal crop levels, particularly if market responses for preferred crops are widely variable. In the aggregate, individual preferences are lost and optimal solutions tend to be produced. However, while the solutions may not correspond perfectly with reality, the estimated changes provide an indicator of changes that could occur given a certain scenario.

At least three potential modeling approaches could be used to gain insight into the problems for this task: input-output analysis, dynamic simulation, and linear programming. Each approach is discussed briefly.

Input-Output

For the problem under consideration in this task, input-output analysis provides an indication of societal resource changes that might occur given a set of final demand changes for different crops. The various crop demand changes necessary for gasohol production are postulated and used to provide an indication of various resource alterations that should be made to accommodate the final demand changes. Individual price changes for each sector's output can be estimated from the estimated resource changes. As an overall technique for estimating the impacts of gasohol production on the economy, input-output analysis would be a useful technique.

In order to use an input-output approach for detailed analyses, a large number of individual agricultural sectors would be necessary, i.e., probably one sector for each crop. The variance in sector production technology for different crops is minimal which leads to insignificant solutions. Further, supply response changes for each crop cannot be estimated using input-output analysis. Thus, while input-output might be a good method for estimating aggregate impacts of gasohol production, the technique does not provide the level of detail required for a crop-by-crop analysis.

Dynamic Simulation

Implementing a dynamic simulation model means many supply and demand relationships must be estimated. Linear regressions are used to analyze historical data and estimate various production parameters. Appropriate relationships indicating changes in supply and demand schedules would be included in the model. After adjusting the model for recent historical time period changes, the model may be used to forecast future changes. As gasohol production is phased in, market and crop changes can be observed. A dynamic simulator model has many strengths; however these are two drawbacks. First, the model is time consuming to formulate and expensive to develop. Second, the model may not be completely applicable in situations where large supply changes are undertaken in response to a new emerging technology. That is, behavioral changes of farmers may change the supply schedule as crop demand rises. The behavioral changes might invalidate the use of the parameters estimated from historical data. However, if sufficient time and monetary resources are available, these drawbacks might be resolved, and the dynamic simulation approach would provide very detailed results.

Linear Programming

A linear program model is capable of solving for an optimal solution while satisfying any number of linear constraints. While meeting specified constraints the model allocates resources, such as land, in a manner that produces an optimal situation. Linear programming provides a good framework for analysis as it allows the implications of a change in any particular parameter to be measured. A linear program model also is capable of measuring increases in the cost of production as crops compete for land resourses. Therefore, the potential for estimating supply curves for each crop exists.

The literature reviewed two linear programming models that already have been used in the agricultural area. These models are the Purdue Agricultural Sector Model and the Texas A&M Agricultural Sector Model. Each of these models have been used to estimate the impact of producing alcohol for fuel on the agricultural sector.

The Battelle Model

On the basis of the previous criteria, a linear programming approach was selected for the model. It was determined that a supply model driven by exogenous demand variables would be developed for the purpose of this study. The model described in the following pages provides a representation of the overall capabilities of using this linear programming approach. Although what is presented is not a refined linear programming model, the structure of the model and initial model results indicate that a model such as the one described could be refined to produce meaningful results for policy analysis.

Assumptions

The underlying assumptions for the Battelle Model are summarized below. Each assumption is described in greater detail in the order summarized and consist of basic assumptions, construct or additional assumptions.

(1) Farmers will select crops for production in an attempt to maximize profits.

(2) Land is limited for agricultural use in the Corn Belt Region. As new crops are planted for alcohol production, and crop land is used for production, increasingly poorer quality land is cultivated for production. Six types of land classes were identified for this model; each class represents a different quality of land with different costs, yields, and fertilizer requirements for each crop.

(3) Production costs and selling prices of each crop will increase as lower quality land is brought into production in a phased alcohol production program.

(4) The Corn Belt Region was treated as a single production unit.

(5) Six initial crops were studied: corn, soybeans, winter wheat, grain sorghum, oats, and alfalfa. Sweet sorghum production was added as a feedstock for alcohol production.

(6) The base year is 1977. All estimated prices are measured in 1977 prices.

(7) Societal requirements for protein, starch, and alcohol production must be fulfilled each year. As the population increases these requirements increase. The requirements were established assuming 1977 actual production levels

measured the necessary requirements for society with no surplus carryover. In subsequent years demand increased by the percentage growth in population. Alcohol demand was phased in exogenously according to a policy scenario.

(8) Minimum production levels equal to the average regional crop production for 1972-1977 must be met for each crop for both on-farm use and off farm sales. This assumption accounts for the taste and preference spectrum of consumers.

(9) Maximum production levels were established for each crop. For most situations the maximum crop production was five percent greater than the largest crop during the period 1967-1977. This assumption accounts for both the taste and preference spectrum as well as satisfying the requirement that sudden large increases in crop production for only one year are not expected.

(10) Nitrogen, phosphates and potash are the fertilizer assumed to be used for crop production and supplies of these fertilizers are assumed to be available throughout the analysis period.

(11) Market selling prices for each crop in 1976 were used as proxies for the expected selling price in 1977. An exception was made for grain sorghum where the 1977 actual selling price was used as a proxy for the expected selling price in 1977.

(12) Production of each crop was assumed to equal consumption; therefore, carryover remains constant.

(13) Sweet sorghum yields, costs, and maximum production levels were assumed over time using reasonable production schedules. Using this production schedule for sweet sorghum yields, costs and maximum production levels, the crop was gradually phased into production between 1981 and 1985.

Basic Model Assumptions. The model assumes that farmers who supply all crop production are seeking to maximize profits. Profit is the difference between a farm revenue and costs. In equation form:

$$\text{Max } P = R - C \tag{1}$$

where P = Profit

R = revenue

C = costs

The maximization of profits occurs while meeting several constraints. The basic theory is that limited land is available for growing crops. As the demand for gasohol increases, the demand for additional land increases. Once all high quality land is being used for agriculture, lower quality land must be used for additonal production which will increase the cost of production. Therefore, an increase in demand for gasohol will ultimately increase the production costs of all crops sold. The model will estimate the crop cost increase along with final production levels for each crop.

The model was tested using the Corn Belt states of Illinois, Indiana, Iowa, Missouri, and Ohio, The Corn Belt Region, therefore, will be treated as a single unit. In this region, nearly all the agricultural land is used for producing six crops: corn, soybeans, winter wheat, grain sorghum, oats, and alfalfa. It was assumed that all the land used in the region could be accounted for by these crops. Later, as sweet sorghum becomes an additional crop in the region it will compete for land with these six crops.

The base year 1977 was chosen for calibrating the model. This is both the most recent year for which adequate revised published data are available and also represents a typical production year in the Corn Belt. In addition, the national economy was reasonably stable in 1977. All prices used in the model and in subsequent simulations are measured in real 1977 dollars. Inflation effects should not be included in a resource evaluation analysis.

The period of estimation was 1980 through 1985. Once the base year was established, projections for policy impacts were made for each year, 1980 through 1985.

Constraints. Land is the first and most important constraint limiting profit maximizator. The constraint may be written as:

$$L_i \leq L_{MAX}\, i \qquad i = \text{land type} \qquad (2)$$

where L_i = the acres of land type i placed into production

$L_{MAX}\, i$ = the maximum acres of land type i available in the Corn Belt

Six types of land were used in this model. Table 22 provides a description of each type and a value for $L_{MAX}i$. For each crop, different crop yields,

TABLE 22. DESCRIPTIONS OF LAND TYPE AND AVAILABLE ACREAGE IN CORN BELT

Land Type[a]		Million Acres Available
1	Cropland of Land Class 1--Suited to a wide range of crops; nearly level; low erosion hazard; productive soils; can be intensively cropped; favorable climate.	11.05
2	Cropland of Land Class 2--Some limitation on suitable crops; require conservation practices to prevent deterioration or improve air and water relationship within soil.	50.77
3	Cropland of Land Class 3--Limitations restrict; (a) amount of clean cultivation; (b) timing of planting, tillage, and harvesting, and (c) choice of crops; require conservation practices more difficult to apply and maintain than those on class II land.	23.00
4	Cropland of Land Class 4--May be suited to only two or three common crops; yields may be low in relation to inputs over a long period; management and conservation measures more difficult to apply than for those on class III land.	5.03
5	Converted Pastureland of Land Class 1.	1.49
6	Converted Pastureland of Land Classes 2 and 3.	17.55
	Total Land Available.	108.89

Source: "Growing Energy" Land for Biomass Farms, Kathryn A. Zeimetz, USDA, June, 1979. Tables 10 and 13; and 1977 SCS National Erosion Inventory Estimates, December, 1978, National Summary Table B.

(a) Land Types 7 and 8 were considered unfit for agricultural production.

production costs, and fertilizer requirements are estimated for each and type. Since unit production costs increase as lower quality land is brought into production, the model will always assign production to all of land type 1 before going on to land type 2, etc., as a means of maximizing profits. Thus the higher cost, lower quality land will be assigned production last; such conditions correspond to the real world.

A second set of constraints is that crop production must satisfy societal requirements for protein, starch (energy), and alcohol. In 1977 the required production levels for protein and starch were estimated. As the population increases over time additional societal need for protein and energy is both perceived and estimated. Alcohol production is phased in according to an assumed production schedule. The alcohol production requirements were zero in 1977. Since crop production must meet the overall needs of society, the lower production bounds are established. The constraints that must be met are:

$$_{i}\ \text{Protein}_{i} \geqq \text{Protein}_{s} \qquad (3)$$

$$_{i}\ \text{Starch}_{i} \geqq \text{Starch}_{s} \qquad (4)$$

$$_{i}\ \text{Alcohol}_{i} \geqq \text{Alcohol}_{s} \qquad (5)$$

i = seven crops

where Protein_s, Starch_s, Alcohol_s refer to societal need for each item

Protein_i = protein contained in crop i's total production

Starch_i = starch contained in crop i's total production

Alcohol_i = alcohol contained in crop i's total production

Crops may be used on the farm for feeding purposes, sold at market prices for human use within the region, sold for off-the-farm feeding, exported out of the region, or held for carryover (stored).

Minimum production bounds for each crop are an additional constraint for each end use. The minimum production levels are assumed to equal the average regional crop production for the period 1972-1977, for each end use.

$$\text{Production}_{ij} \geq \text{Minimum}_{ij}$$

i = seven crops

j = used on farm or sold

where Production_{ij} = crop i's total production for end use j

Minimum_{ij} = average crop i production over period 1972-1977, for end use j

The minimum production constraint is appropriate as a realistic measure of the demand for each crop. For example, societal tastes for a crop may vary from the optimal necessary production of protein and starch, clearly indicating that consumers do not always desire the commodity that is least expensive to satisfy their needs. The minimum constraints recognize such facts.

Maximum production bounds are needed to account for the other end of the taste and preference spectrum. The same rationale concerning tastes and preferences again is applicable. However, the maximum production level achievable by farmers is assumed to be a percentage of the highest production level that actually occurred during the period 1967-1977. This assumption reflects the fact that production can only be expanded at a specified rate above that achieved in prior years. The constraints are:

$$\text{Production}_i \leqq \text{Maximum}$$

i = seven crops

where Maximum_i = (1+P) x maximum production of crop i during 1967-1977.

For most situations the value of P was set to .05. This value indicates that the maximum crop yield that can be produced over time is 5 percent larger than the historically largest production during this period 1967-1977. For grain sorghum, wheat, and corn additional production is perceived as possible each year during the five year period as these crops are primary inputs for the production of alcohol fuels. Each crop has an expected growth potential that will be phased over the six year time period. For grain sorghum, wheat, and corn, P was .05 in in 1977 and 1980, .10 in 1981, .15 in 1982, .20 in 1983, .25 in 1984, and .30 in 1985.

Additional Assumptions. Several additional assumptions were required to make the model as realistic as possible. Each is discussed briefly in the following section.

Fertilizer requirements were based on specified rates per acre for each land type. The three fertilizer components are nitrogen, potash, and phosphates. Once the model has estimated the optimal crop production pattern, estimates are generated for the quantity of fertilizer needed for production. It was assumed that adequate supplies of fertilizer would be available throughout the model time period in the Corn Belt region.

The profit level was defined as the difference between revenues and costs. The method of obtaining cost data will be discussed in the following section. Revenues were measured on a per unit basis, either a bushel or a ton. In establishing the 1977 base prices it was decided that farmers would grow crops based on expected selling prices. The most reasonable expected selling price was the market price in 1976. Thus the 1976 crop prices were used as a proxy for expected selling price, in 1977. Grain sorghum represents an exception to the selling price proxy because 1976 selling prices for grain sorghum were high and resulted in sizable production increases of grain sorghum in 1977. In 1977 the grain sorghum market was glutted and prices fell significantly. therefore, Battelle hypothesized that the 1977 selling prices along with the 1977 production levels would be appropriate price and quantity proxies for the profit maximizing model. The final expected prices used in the model are shown in Table 23.

Another assumption was that production of each crop would equal consumption. This means that the carryover at the end of each year would remain constant. The amount of crop i produced on each land type, multiplied by the yield for each land type, and summed, equals production. The sum of the desired crop end uses equals consumption. In the model, production and consumption are equal for each time period.

TABLE 23. PRODUCTION COSTS AND EXPECTED SELLING PRICES FOR SELECTED CROPS FOR 1977

	Production Cost	Expected Selling Price	Ratio Selling Price/Cost
CORN ($/bushel)	2.16	2.29	1.0602
SOYBEANS ($/bushel)	4.88	7.48	1.5328
WHEAT ($/bushel)	2.63	2.98	1.1331
OATS ($/bushel)	1.57	1.46	0.9299
ALFALFA ($/ton)	42.88	55.52	1.2948
GRAIN SORGHUM ($/bushel)	2.00	2.65	1.3250

Source: Agricultural Prices, Annual Summary 1976, Crop Reporting Board--Statistical Reporting Service, USDA, June, 1977.

Agricultural Statistics 1978, USDA.

Sweet sorghum, as the new competing crop, required that some assumptions be made regarding entry to the agricultural marketplace. Yields per acre are assumed to rise as technological know-how increases. A 10 percent rise in yield per year was assumed for the introductory years. Sweet sorghum was also assumed to occupy an increasing share of the gasohol market as it becomes better known.

The alcohol market share and acreage yields for sweet sorghum are given in Table 24. The selling price for sweet sorghum, in 1977 dollars, was assumed to be $10.11 per ton (fresh weight). The production cost was determined to be about $243 per average acre. Sweet sorghum was assumed to grow on a mix of average land types. Thus its production

TABLE 24. SWEET SORGHUM YIELD AND MARKET PENETRATION OVER TIME

	1981	1982	1983	1984	1985
YIELD (tons/acre fresh weight)	33.0	36.3	39.9	43.9	48.3
ALCOHOL PRODUCTION MARKET PENETRATION (percent)	0	1	3	10	15

Source: BCL estimates.

was assigned in relative proportion to land types 1 through 4 actually available in the region, for example, 12.3 percent of sweet sorghum is grown on land type 1, 56.5 percent on land type 2, 25.6 percent on land type 3, and 5.6 percent on land type 4. As crop yields increase, sweet sorghum was hypothesized to become increasingly profitable.

The alcohol content of the crops was established for each production level--11.7 gallons of alcohol per ton of sweet sorghum, 2.6 gallons per bushel of either corn or grain sorghum, and 2.3 gallons per bushel of wheat. The other crops were not considered to be useful for alcohol production.

Data for Model

Data sources are provided in Appendix C. The less obvious data construction of some variables from the basic sources are discussed in this section.

Land Availability. Land availability was estimated by first using the data given by Zeimetz.[16] Her estimates were normalized to the total available land from the National Erosion Inventory Estimates. The latter estimates were a better definition of total land available in the Corn Belt.

Costs and Yields. The most difficult items to ascertain are the cost of production, yield, and fertilizer requirements by land type for each crop. The method of estimation was based upon obtaining cost, yield, and fertilizer requirements for each crop for many different regions within the Corn Belt. Within each region, the average yield and standard deviation were calculated for each crop. The highest and lowest crop yields were assumed to be grown on land types 1 and 4 respectively. Yields were assumed to follow an exponentially declining distribution over the land types. The actual population of observed yields by land type was assumed to be normally distributed. To estimate yields the known percentage of each land type available was used along with the mean yield and standard deviation for each crop. Yields were mapped to the normal curve distribution of land types available in the region. Using this assumption means that observed crops are grown proportionately on all land types with declining yields on subsequently lower quality land. The results include a yield figure for each land type where the average yield is grown on the 50th percentile quality of land.

With this yield distribution it is possible to estimate "break" points in yields where land type 1 merges into land type 2. Applying these break points to the original list of disaggregated yields, allows regions to be separated into land types. Within the land type, both unit cost and fertilizer requirements were averaged.

Special assumptions were made for land type 4 costs. The cost of production for land type 4 was set to be one-sixth higher than the cost of production on land type 3, due to the marginal quality of the land. All of land types 5 and 6 are presently pasture and rangelands. Land type 5 yields were assumed to be the same as land type 1, once conversion has taken place. The costs for land type 5 were set one-third higher than land type 1 costs to indicate conversion cost. Additionally, fertilizer requirements on type 5 land were assumed to be one-third higher than the fertilizer costs for land type 1. Since land type 6 was composed of converted land type 2 and 3, a procedure similar to that used for land type 5 was used for land type 6. Land type 6 had the same yield as the average of land types 2 and 3, with a cost one-third higher than the average cost of land types 2 and 3, and fertilizer needs one-third greater than the average for land types 2 and 3.

Grain sorghum is grown only in Missouri and limited production data were available. Since most land in Missouri falls in land types 2, 3, and a limited amount of land type 4, it was assumed that no grain sorghum was grown on land type 1. The average figures for the State were applied to land type 3. Distributions of costs and yields for land types 2 and 4 were obtained around this average by using similar cost and yield distributions obtained from all other crops. Fertilizer needs were set identical for all land types 2, 3, and 4.

The final cost and yield raw data used in the model are presented in Appendix D.

Protein, Starch, Alcohol Demand. The total protein and starch produced during 1977 was estimated using crop production data average weight per unit in conjunction with the protein and starch content of each crop (percent by weight). The amounts of protein and starch produced were calculated for both crops used on the farm and for crops sold off the farm. In each case, the 1977 estimates was assumed to represent societal protein and starch needs from the Corn Belt. Effectively, this assumption implies a constant carryover existed during 1977. Over time as the population grows, additional protein and energy needs must be met. More livestock will be consumed so that livestock feed requirements will grow at the same rate as the population, assuming constant feed conversion efficiencies. The assumed rates of growth are 1 percent per year in this initial modeling effort. These growth rates can be changed later if desired. The overall calculated requirements used in the model are shown in Table 25. Alcohol requirements are noted at the bottom of Table 25. Crop production must be sufficient to meet all these exogenous demands.

TABLE 25. PROTEIN, ENERGY, AND ALCOHOL, REQUIREMENTS OF SOCIETY

	1980	1981	1982	1983	1984	1985
PROTEIN-USED ON FARM (billion pounds)	35.46	35.81	36.17	36.53	36.90	37.27
PROTEIN-SOLD (billion pounds)	64.20	64.84	65.49	66.14	66.81	67.47
STARCH-USED ON FARM (billion pounds)	61.84	62.46	63.09	63.72	64.36	65.00
STARCH-SOLD (billion pounds)	111.15	112.26	113.38	114.51	115.66	116.82
ALCOHOL (million gallons)	130.0	200.0	350.0	600.0	800.0	950.0

Source: Calculated via assumptions stated in the text.

Model Operation

With the model formulated, constraints established, and necessary data collected, the model was coded and run on the computer. A diagram of the steps in the model are shown in Figure 12. The first analysis over the 1977-1985 period was made using the expected selling prices given in Table 23. The model hypothesized that farmers attempted to maximize profits while faced with the expected set of selling prices.

The model base year results and actual crop production are compared in Table 26 for 1977. The model results appear to be reasonable estimates. Again it should be stressed that while the model rarely if ever exactly depicts reality, the estimates are best interpreted using proportioned changes in estimates over time. Using proportional estimates eliminates biases due to the errors in base year estimates and future year estimates.

The model was run through 1985 as the economy faced the new demands for energy, protein, and alcohol. The results are shown in Table 27. The model estimated that all new demands were satisfied by increasing production of corn and grain sorghum along with additional production of sweet sorghum. The other crop estimates are essentially unchanged. Detailed

FIGURE 12. Flow Diagram of Battelle Linear Model for Sweet Sorghum

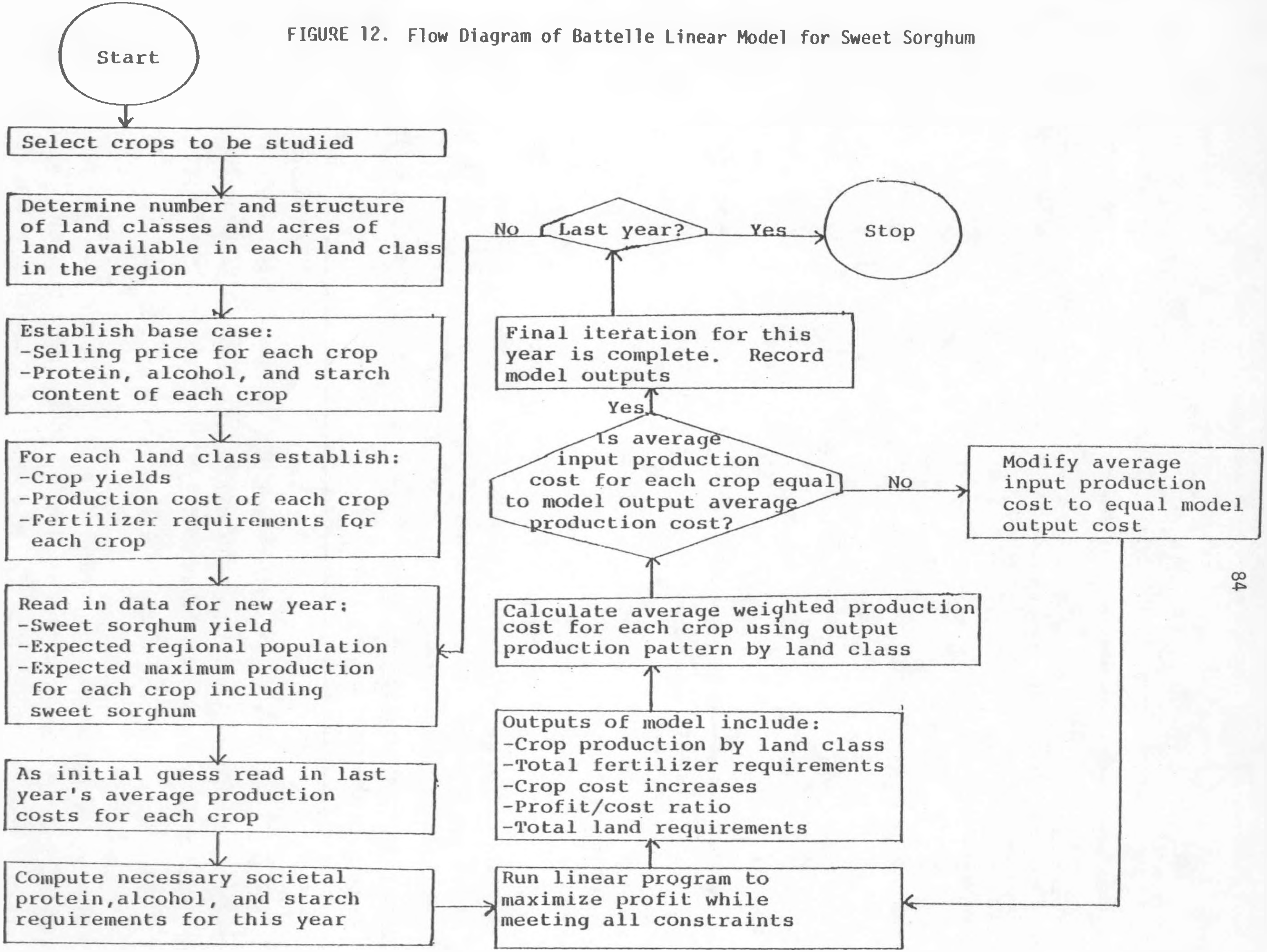


TABLE 26. ACTUAL AND MODEL ESTIMATED CROP PRODUCTION (MILLIONS OF UNITS), AND LAND USED (MILLIONS OF ACRES), 1977

	Actual Production	Model Estimates
CORN (bushels)	3470.5	3533.6
SOYBEANS (bushels)	1000.6	1050.7
WHEAT (bushels)	268.4	281.8
OATS (bushels)	143.1	144.2
ALFALFA (tons)	22.8	23.9
GRAIN SORGHUM (bushels)	75.5	79.3
LAND USED (million acres)	80.76	84.82

Source: Model estimates and Agricultural Statistics, 1977.

TABLE 27. MILLION UNITS GROWN UNDER BASE PRICE ASSUMPTIONS

	1977	1980	1981	1982	1983	1984	1985
CORN (bushels)	3533.6	3713.2	3789.6	3896.0	4040.8	4156.0	4236.0
SOYBEANS (bushels)	1050.7	1050.7	1050.7	1050.7	1050.7	1050.7	1050.7
WHEAT (bushels)	218.8	212.7	212.7	212.7	212.7	212.7	212.7
OATS (bushels)	144.2	144.2	144.2	144.2	144.2	144.2	144.2
ALFALFA (tons)	23.9	23.9	23.9	23.9	23.9	23.9	23.9
GRAIN SORGHUM (bushels)	79.3	79.3	83.1	86.9	90.6	94.4	98.2
SWEET SORGHUM (tons)	0.0	0.0	0.0	0.3	1.5	6.8	12.2

Source: Model estimates.

study of the results indicates that wheat and oats were assigned to lower quality land over time as more corn was grown on type 2 land. This change increased wheat and oats production costs, making the crops unprofitable. Thus production of wheat and oats was the minimum amount possible. Meanwhile, soybeans and alfalfa were very profitable crops and were produced in the maximum acreage permitted for all six years. Changes in crop selling prices would affect these results.

As production costs increase because crops are being assigned to lower quality land, one might hypothesize that selling prices for these crops also might rise. As production costs rise, supply declines causing a disequilibrium supply and demand. A price increase would bring supply and demand back to equilibrium.

To establish the equilibrium point, the cost of producing an average unit of crop i was calculated using a weighted average of the land class production costs for crop i. This estimate was called the supply price. The demand price should be equal to the selling price of a unit of crop i used on the farm, since no profit was assumed for crops used on the farm. Furthermore, the selling price for units of crop i sold off the farm should be in the same sold/used price ratio for crop i as given initially in Table 23. To calculate the equilibrium point, the following mechanism was used. First, the average production cost was calculated (supply price) and the on farm selling price was equated to the average production cost. The off farm selling price was calculated using the used/sold price ratios in Table 23. The model was run again, producing new crop yields. From the model results of new crop yields the average cost of production again was calculated. The loop was repeated until the supply price equaled the demand price for all crops simultaneously. In practice it required three or four model runs for each year to reach market equilibrium.

Results

The iterated prices that placed the modeled economy into equilibrium are shown in Table 28. Of course the price for units sold off the

TABLE 28. UNIT PRICES WHERE PRICE EQUALS AVERAGE PRODUCTION COST, IN CONSTANT 1977 DOLLARS

	1977	1980	1981	1982	1983	1984	1985
CORN ($/bushel)	2.10	2.10	2.10	2.10	2.10	2.10	2.10
SOYBEANS ($/bushel)	5.04	5.04	5.04	5.04	5.04	5.04	5.04
WHEAT ($/bushel)	2.50	2.50	2.50	2.50	2.60	2.85	3.07
OATS ($/bushel)	1.50	1.50	1.52	1.86	1.99	1.99	2.00
ALFALFA ($/ton)	44.35	44.33	44.32	44.30	44.30	44.30	44.30
GRAIN SORGHUM ($/bushel)	1.90	1.90	1.90	1.90	1.90	1.90	1.90
SWEET SORGHUM ($/ton)	*	*	*	10.11	10.11	10.11	10.11

*No sweet sorghum production in these years.

Source: Model estimates.

farm was obtained by multiplying Table 28 results by the ratios contained in Table 23. The percentage price changes are the same for either situation. The only significant price changes occured with wheat and oats because the production occurs on increasingly lower quality land. Crops such as corn used larger amounts of high quality land from 1980 through 1985. The price remained constant for corn. Including additional land types to the model data base would result in price changes for corn that must occur as production increases.

For the set of equilibrium prices the crop production schedule is shown in Table 29. These results reflect the effect of market equilibrium conditions being satisfied. However, the sharp increase in wheat production in 1984 and 1985 appears unrealistic, even with the higher prices noted in Table 28. Also, the one-year rise in oats production to 247 million bushels in 1983, with a decline back to 144 million bushels in 1984 seems illogical.

As increasing amounts of sweet sorghum are grown, farmer profits increase. Offsetting higher farm profits of sweet sorghum production is the impact of production on less favorable lands. The over-all effect is shown in Table 30. The profit/cost ration gradually declines more than 6 percent from 1977 to 1985. If farmers expect to keep overall aggregate profits at the same level between 1977 and 1985, some general price increase will be necessary. Revenues from selling all crops must rise to keep the profit/cost ratio at the same level as in 1977. One can calculate a general price increase of about 1.21 percent in 1985 for all crops is necessary to reinstate the profit/cost ratio to 0.2208. Somewhat smaller price increases would be necessary for each of the preceeding years. Both the general price increase and the equilibrating prices are shown in Table 28.

Additional results also are tabulated in Table 31, which indicate the actual acres of land used for each crop. Table 32 presents the fertilizer requirements for the estimated crop production levels. During the period, 1977-85, potash, phosphate and nitrogen requirements increased by 11.5 percent, 13.1 percent, and 16.5 percent respectively.

TABLE 29. MILLION UNITS GROWN WHERE PRICE EQUALS AVERAGE PRODUCTION COST

	1977	1980	1981	1982	1983	1984	1985
CORN (bushels)	3533.6	3700.3	3755.0	3882.1	4005.2	4099.7	4115.6
SOYBEANS (bushels)	1050.7	1050.7	1050.7	1050.7	1050.7	1050.7	1050.7
WHEAT (bushels)	281.8	212.7	212.7	212.7	212.7	249.4	348.9
OATS (bushels)	144.2	144.2	144.2	144.2	246.7 *	144.2	144.2
ALFALFA (tons)	23.9	23.9	23.9	23.9	23.9	23.9	23.9
GRAIN SORGHUM (bushels)	79.3	79.3	83.1	86.9	90.6	94.4	98.2
SWEET SORGHUM (tons)	0.0	0.0	0.0	0.3	1.5	6.8	12.2

Source: Model estimates.

* This estimate appears unrealistic, and would need to be re-examined in subsequent model refinements.

TABLE 30. PROFIT/COST RATIO AND PERCENT DECLINE FOR AGGREGATE PRODUCTION FROM SEVEN CROPS

	1977	1980	1981	1982	1983	1984	1985
Profit/ Cost	0.2208	0.2170	0.2135	0.2113	0.2066	0.2069	0.2063
% Decline/ From 1977	0.00	-1.72	-3.42	-4.28	-6.44	-6.27	-6.57

Source: Calculated from model estimates of cost of production and selling revenue.

TABLE 31. THOUSANDS OF ACRES USED IN CROP PRODUCTION

	1977	1980	1981	1982	1983	1984	1985
Corn	36,444	38,163	38,728	40,038	41,308	42,283	42,446
Soybeans	32,338	32,338	32,338	32,338	32,204	32,062	32,023
Wheat*	5,917	4,467	4,467	4,467	4,840	6,707 *	9,680 *
Oats*	2,241	2,241	2,542	3,215 *	4,057 *	2,680	2,442
Alfalfa	6,865	6,596	6,500	6,286	6,243	6,243	6,243
Grain Sorghum	1,017	1,017	1,065	1,113	1,162	1,210	1,259
Sweet Sorghum	0	0	0	8	39	156	252
TOTAL LAND	84,822	84,822	85,640	87,465	89,853	91,341	94,345

Source: Model estimates of crop production.

* Estimates appear to be unrealistic, with unusually sharp increases in production acreage. However, as wheat and oats are forced onto less productive land, increased acreage would be required to satisfy demand requirements.

TABLE 32. FERTILIZER REQUIREMENTS (MILLIONS OF POUNDS/YEAR)

	1977	1980	1981	1982	1983	1984	1985
Potash	4,664	4,715	4,756	4,852	4,981	5,037	5,200
Phosphate	3,781	3,810	3,848	3,935	4,046	4,105	4,276
Nitrogen	5,259	5,388	5,460	5,625	5,799	5,926	6,128

Source: Model estimates.

Finally, Table 33 provides estimates of the percentage of alcohol produced from each crop over the six year time period. Initially corn obtains an increasing share of alcohol production as corn production levels increase rapidly as corn. Therefore, while the total gallons of alcohol produced from grain sorghum increases each year, the market share declines. Sweet sorghum production is phased as assumed, beginning in 1982. The alcohol production from wheat begins in 1984 and replaces the grain sorghum. The change depicted by the model results from grain sorghum to wheat indicates that from a total resource allocation standpoint, wheat would satisfy the alcohol demand while grain sorghum could satisfy the starch and protein demand more cost effectively. However, it is completely illogical to imply that wheat at $3.07 per bushel in 1985 would be used for alcohol production in lieu of grain sorghum at $1.90 per bushel. Therefore, it is obvious that adjustments in the model are required to correct this deficiency. The results of the entire table will be greatly altered if different assumptions about the rate of potential growth in crop production are made. The model results as exhibited merely indicate the type of analyses that can be made with this linear program.

TABLE 33. PERCENT OF ALCOHOL PRODUCTION BY CROP TYPE

	1980	1981	1982	1983	1984	1985
Corn	27.1	47.7	66.3	78.3	79.5	52.0
Wheat*	0.0	0.0	0.0	0.0	10.5	33.0
Grain Sorghum*	72.9	52.3	32.7	18.7	0.0	0.0
Sweet Sorghum**	0.0	0.0	1.0	3.0	10.0	15.0

* Battelle does <u>not</u> believe these <u>preliminary</u> model results are indicative of the likely evolution of United States' alcohol production. Historical evidence indicates that wheat is a much more expensive feedstock for alcohol production than grain sorghum. Also many alcohol plants built to process grain sorghum into alcohol would not be located in wheat producing regions, which would inhibit switching from grain sorghum to wheat.

** This market penetration schedule for sweet sorghum was assumed as an input to the model.

Source: Calculated from model estimates.

Interpretation of the Results

There are difficulties in using the preliminary results of the model as an indication of the impact of alcohol fuels on the Corn Belt agricultures. First, the model used six land types. Additional land types or more detailed land descriptors should be added to smooth the production cost curves and crop allocation by land type. Presently there exists the potential for large switches in crop production on various land types because of small price changes. Greater detail within the model would help to overcome supply curve shifts.

Second, the estimates of profits in Table 30 are only estimates. Much of the data for this model were aggregated and greater cost detail for this model would result in profit estimates closer to reality. However, the proportional changes in profits over the six year period are represented by the model.

Third, the results of Table 33 indicate a shift from feed grains to food grains for alcohol production. The historical U.S. crop price situation does <u>not</u> indicate such a shift will actually occur. The reader must remember that different assumptions will result in different resource allocations. In addition, no exports were assumed in the regional model. Therefore, crops were assumed to be allocated within the Corn Belt regions.

Fourth, the preliminary model does not indicate the proper magnitute of the price effects. For example, corn prices do not respond to supply differences as might be hypothesized. The addition of more land subcategories within class 1 through 6 should result in greater impacts on prices.

Finally, changes in the general price level of 1.2 percent for all crops between 1977 and 1985 would result in corresponding price increases for feedstocks, food, etc. These impacts should be adjusted more easily as the model variables are expanded.

Possible Extensions of the Battelle Model

As mentioned in the interpretation of results, the model should be enlarged to include more subcategories within the various land classes. These subcategories are necessary to fully define production costs and obtain a more optimum allocation of resources. Separate data for each state would be placed into the model, rather than aggregating the data on a regional basis. The disaggregation of the inputs would result in greater delineation of changes in the output, particularly price changes of various crops as production cost changes.

For the purposes of this report, only six crops were considered to be produced in the corn belt region. Additional crops could be added to the model to make a more realistic delineation of cropping patterns. In addition, the impact of exports for livestock and human consumption also could be added to the model. Once the model is refined, several step wise progressions could be taken to extend the usefulness of the model for policymaking decisions. First, the model could be used to estimate supply curves for various crops. These curves could be generated by running a model under varying price assumptions for several commodities and use the model to generate the supply curves for other commodities. By using a step-wise refinement process, elasticities and cross elasticities among the various commodities could be estimated. These data then could be utilized by the Department of Energy in assessing the impact of various policy scenarios on U.S. agricultural crop production.

The final extension in the model could be the development of demand estimates as prices change. Presently, the model accepts demand as an exogenous variable. By using historical data to develop approximate price elasticities for the various elements of demand, extensions could be made utilizing the price elasticities and demand projections. These extensions would be based upon forecasted changes of supply and the expected impacts on demand.

The extensions just enumerated would add an element of realism to the model. Not only would the model be more adaptable to the real world, but also would provide the Department of Energy with estimates of regional changes in supply and income, and thereby result in a more understandable energy policy.

APPENDIX A

BASELINE INVESTMENT AND MANUFACTURING COSTS TO PRODUCE ETHANOL FROM SUGARCANE AND MOLASSES IN LOUISIANA, 1978.

TABLE A-1. COST ESTIMATE SUMMARY FOR FACILITY TO MANUFACTURE ANHYDROUS ETHANOL FROM SUGARCANE, 1978 DOLLARS.

I. Juice Processing and Steam Generation

Code No.	Description	Cost, $	
00-00-00	Site preparation	535,000	
01-00-00	Cane handling	2,754,000	
02-00-00	Milling	6,844,000	
03-00-00	Juice processing	4,366,000	
06-00-00	Bagasse handling and steam generation	11,084,000	
08-00-00	Electrical generation	2,268,000	
09-00-00	Water processing	628,000	
10-00-00	Chemical preparation	334,000	
11-00-00	Fuel handling	128,000	
12-00-00	Warehousing	223,000	
13-00-00	Plantwide piping	4,400,000	
14-00-00	Plantwide services	3,770,000	
15-00-00	Office and employee	280,000	
	facilities	187,000	
16-00-00	Shops	187,000	
	Subtotal		37,801,000
	Indirect Costs		
	Spare parts	1,325,000	
	Field staff and expenses	570,000	
	Small tools and rentals	475,000	
	Temporary facilities	115,000	
	Builder's risk and insurance	795,000	
	Start-up services	475,000	
	Testing services	115,000	
	Contractor's fee	2,380,000	
	Contingency and miscellaneous	1,170,000	
	Subtotal		7,420,000
			45,221,000
	Engineer's cost and fee		3,165,000
	Engineer's travel and living		225,000
	Total juice processing and steam generation cost		48,611,000

TABLE A-1. (Continued)

Code No.	Description	Cost, $	
	II. Fermentation and Distillation		
55-00-00	Mash preparation	310,000	
56-00-00	Fermentation	2,129,000	
57-00-00	Yeast separation and drying	592,000	
58-00-00	Distillation	3,960,000	
59-00-00	Alcohol storage	1,099,000	
60-00-00	Plantwide services	270,000	
	Sub-total		8,360,000
	Indirect Cost		
	Spare parts	295,000	
	Field staff and expenses	125,000	
	Small tools and rentals	105,000	
	Temporary facilities	25,000	
	Builder's risk and insurance	155,000	
	Start-up services	105,000	
	Testing services	25,000	
	Contractor's fee	525,000	
	Contingency and miscellaneous	260,000	
	Sub-total		1,630,000
			9,990,000
	Engineer's cost and fee		700,000
	Engineer's travel and living		50,000
	Total fermentation and distillation		$10,740,000
	III. TOTAL COMPLETE FACILITIES		59,351,000
	Say		$59,500,000

Source: E. S. Lipinsky, et. at. Sugar Crops as a Source of Fuels: Volume II: "Processing and Conversion Research", report to U.S. Department of Energy, Battelle Columbus Division; August 31, 1978.

TABLE A-2. PROJECTED SELLING PRICE FOR ANHYDROUS ETHANOL, FROM SUGARCANE: 90-DAY SEASON AND CANE AT $13.50/TON, 1978 DOLLARS.

Capital cost		$59,500,000
Initial equity		23,800,000
Borrowed		35,700,000
Basis: 10 years annual average		
Short tons of cane ground per day		9,000
Gallons of 99.5° GL alcohol produced per day		140,400
Length of processing season, days		90
Gallons of 99.5° GL alcohol produced per year		12,636,000
Short tons of cane ground per year		810,000

	$/Gallon of 99.5° GL Alcohol	Annual Amount, $
Production Cost, Before Depreciation and Interest		
Cane cost @ $13.50/gross ton	0.87	10,935,000
Salaries, wages, payroll taxes, employee insurance & retirement	0.14	1,800,000
Chemicals	0.02	243,000
Repair parts	0.08	1,012,500
Insurance	0.03	375,000
Total production cost	1.14	14,365,500
Depreciation and Interest		
Depreciation (18 years straight line)	0.26	3,305,556
Average interest (9%)	0.16	1,992,777
Total depreciation and interest	0.42	5,298,333
Total Production Cost After Depreciation and Interest	1.56	19,663,833
Return on Initial Equity (20% before taxes)	0.38	4,760,000
Projected Selling Price	1.94	--

Source: E. S. Lipinsky, et. al. Sugar Crops as a Source of Fuels: Volume II; "Processing and Conversion Research", report to U.S. Department of Energy, Battelle Columbus Division; August 31, 1978.

TABLE A-3. LOAN REPAYMENT SCHEDULE FOR PRODUCTION OF ANHYDROUS ETHANOL FROM SUGARCANE.

Basis:

Plant cost	$59,500,000
Equity (40 percent)	23,800,000
Borrowed (60 percent)	35,700,000
Life of loan	10 years
Interest rate	9 percent

Year	Total Payment	Interest	Amortization Payment	Remaining Balance
1	5,562,777	3,213,000	2,349,777	33,350,223
2	5,562,777	3,001,520	2,561,257	30,788,966
3	5,562,777	2,771,007	2,791,770	27,997,195
4	5,562,777	2,519,748	3,043,030	24,954,166
5	5,562,777	2,245,875	3,316,902	21,637,263
6	5,562,777	1,947,354	3,615,424	18,021,840
7	5,562,777	1,621,966	3,940,812	14,081,028
8	5,562,777	1,267,293	4,295,485	9,785,544
9	5,562,777	880,699	4,682,078	5,103,465
10	5,562,777	459,312	5,103,465	0
Total	55,627,772	19,927,772	35,700,000	--
Average	5,562,777	1,992,777	3,570,000	--

Source: E. S. Lipinsky, et. al. Sugar Crops as a Source of Fuels: Volume II: "Processing and Conversion Research", report to U.S. Department of Energy, Battelle Columbus Division; August 31, 1978.

TABLE A-4. PROJECTED SELLING PRICE OF 95 PERCENT ETHANOL, FROM SUGARCANE MOLASSES 70-DAY SEASON AND 18,000 GALLONS PER DAY OF MOLASSES.

Capital Cost		$4,150,000
Initial equity		1,660,000
Borrowed		2,490,000
Basis: 10 years annual average		
Gallons of molasses used at 80° Brix per day		18,000
Gallons of 95° GL alcohol produced per day		6,667
Length of processing season, days		70
Gallons of 30° Brix molasses used per year		1,260,000
Gallons of 95° GL alcohol produced per year		466,690
	$/Gallon of 95° GL Alcohol	Annual Amount, $
Production Cost, Before Depreciation and Interest		
Molasses values @ 18¢/gallon	0.49	226,800
Operating labor cost (3 men/shift at $7/hr. + 20%)	0.09	42,336
Electrical power cost @ 1.2 KWH/gal. (1 KWH = $0.02)	0.02	11,200
Supplies chemicals etc. ($0.02/gal.)	0.02	9,334
Maintenance cost	0.01	4,000
Fuel cost (at 30¢/gal.) and 0.72 gals./gal. alcohol	0	0
Total production cost	0.63	293,670
Depreciation and Interest		
Depreciation (18 years straight line)	0.49	230,556
Average interest (9%)	0.30	138,992
Total depreciation and interest	0.79	369,548
Production Cost After Depreciation and Interest	1.42	663,218
Return on Initial Equity (20% before taxes)	0.71	332,000
Projected Selling Price	2.13	

Source: E. S. Lipinsky, et. al. Sugar Crops as a Source of Fuels: Volume II: "Processing and Conversion Research", report to U.S. Department of Energy, Battelle Columbus Division; August 31, 1978.

APPENDIX B

Literature Review of Six Agricultural Models

Economic models are a convenient way to organize and present a large amount of data for analyses. Models are particularly useful for testing impacts of a new policy or program before implementation in the sectors they describe. A well-refined model integrating most relevant variables and relationships of a sector, provides useful information without the economical or social cost associated with field testing.

Forecasting the economic impacts of integrating biomass for fuels production into the existing U.S. agricultural system has been examined by three models: The Texas A&M Model, The Purdue Model, and a study by Wisner and Gedel. These models are part of a larger family of agricultural models developed largely for measuring the economic impact of changes in U.S. agricultural structure and operations. The models reviewed in this report are at least of two types: econometric simulation and mathematical programming or activity analysis models. Econometric simulation models include response parameters and dynamic properties which attempt to approximate reality. Mathematical programming models seek optimization solutions which are sometimes quite far removed from reality.

Two recent econometric simulation models have been reviewed. These include POLYSIM and AGRIMOD; and describe U.S. agriculture with different degrees or aggregation. The third model reviewed is a descriptive projection study by Wisner and Gidel. Wisner and Gidel's model cannot be classified realistically as either econometric simulation or a mathematical programming model. The remaining three models reviewed are entirely in the optimization category and include: a spatial agriculture programming model by E.O. Heady, et al., The Texas A&M Model, and the Purdue Model.

POLYSIM: A National Agricultural[8] Policy Simulator

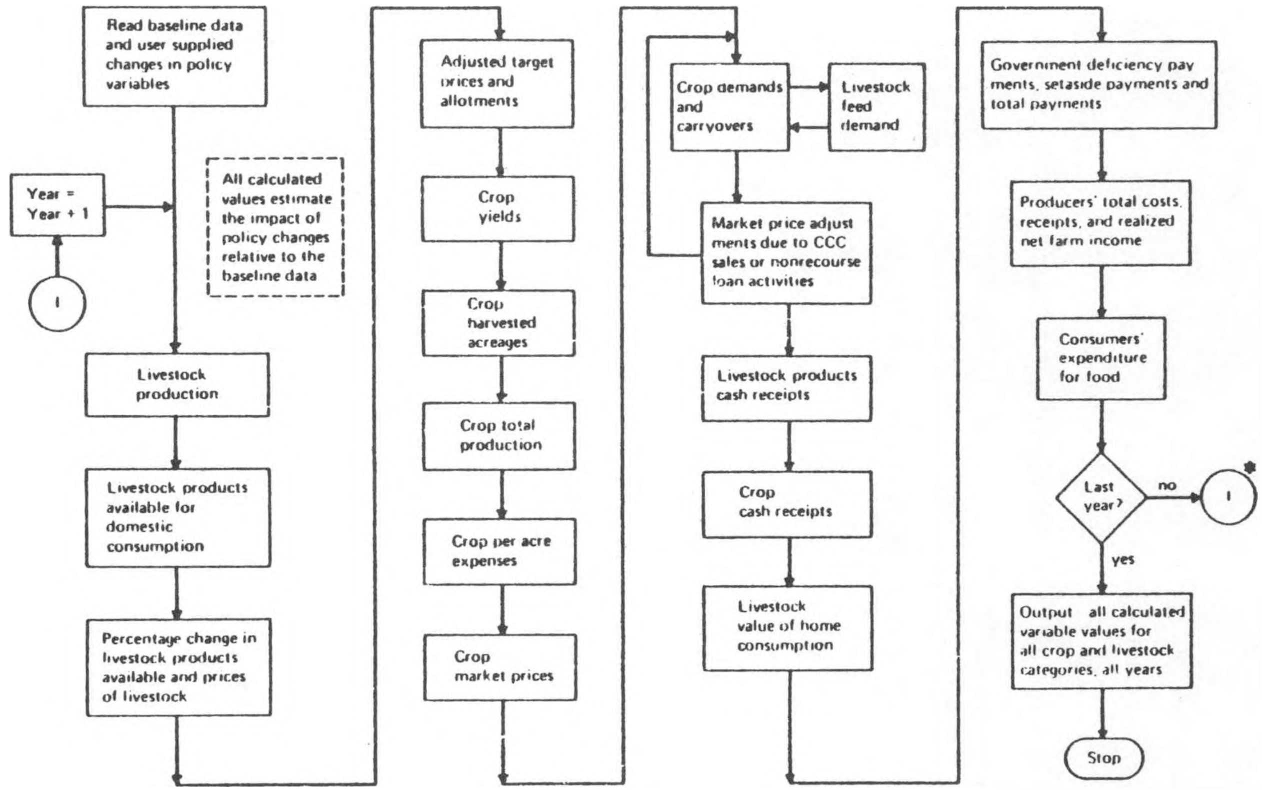
The National Agricultural Policy Simulator (POLYSIM) was developed at Oklahoma State University in 1972 and has been used in several studies.

Impact of the following policies have been analyzed with the model:[9] institution of a specified domestic grain reserve program; changes in target price; allotted acreages; loan rates; set-aside acreages; prices and incomes of individual agricultural sector; net farm income; government costs, and; food expenditures.[2]

The model includes four crop commodities (feed grains, wheat, soybeans, and cotton) and seven livestock commodities (cattle and calves, hogs, sheep and lambs, chicken, turkeys, eggs, and milk). The model baseline, completely made up of forecasted data on the commodities is used as the reference to measure impacts of policy changes. Usually, the model's forecasting applications span over a 3-5 year period. Over this time span, the user can observe policy-related shifts in production, price, use, and farm income for each of the 11 commodity groups. Baseline forecasted data must be available for each of the years being analyzed. Figure B-1 is a flow chart of the computer program for POLYSIM.

The first step of the simulation is a reading of baseline data (forecasts), a determination of the number of years to be simulated, the beginning year, farm program options, and policy variable levels, if necessary. During the first set of steps, the user first modifies any baseline data such as exports, yields, imports, and harvested acres. The second step starts the simulation by calculating livestock production and prices; the third step uses information derived in the model and combines it with import and export demand estimates to determine the amount of livestock available for domestic consumption. The fourth step in the livestock calculation determines the change in livestock product availability as well as the current year's prices for livestock products. The second iteration constitutes a series of calculations to determine crop supplies and production costs for each crop (with needed adjustments in target price and allotted acreages as required by the user). Crop prices and demand are determined in the third iteration. The fourth iteration includes determinations of government payments and producer costs, receipts and income.

Initial or baseline prices and subsequent price changes following the introduction of new policy specifications start the mechanism of the



* Note: The computer is instructed to return to the beginning of its program to simulate another year

FIGURE B-1. FLOW CHART OF COMPUTER PROGRAM FOR POLYSIM

Source: Detailed Description of Polysim, Technical Bulletin T-151, Agricultural Experiment Station, Oklahoma State University and USDA, December, 1978.

stepwise simulation. Simulated livestock prices are a function of the baseline price and cross-price relationships between one particular group and all the other livestock groups. For any crop, prices are determined by the intersection of a perfectly inelastic supply curve (the crop already has been produced) and the expected demand curve.

Direct and cross elasticities for these calculations are endogenous to the model. The user can rely on the values developed by the authors in a lengthy process (literature review, incorporation of new data, and revisions by commodity specialists) or can substitute new calculations. Use of the model can become increasingly difficult if a large portion of the elasticities have to be updated.

POLYSIM's principal intended use is to allow the policy maker to trace changes in the agricultural system through other variables such as yield, cost, demand, stock, and other production variables as well as other aggregated variables.

In order to analyze the impacts on the U.S. agricultural sector of alcohol production from grain or sugar crops, POLYSIM has severe drawbacks. The issue of land allocation cannot be addressed because, as a simulation model, POLYSIM lacks the ability to estimate optimum resource allocation. No spatial considerations are included in the model. Realistically, yields vary tremendously from one area to another. For the same reason, and with the same consequences, transportation costs are not a consideration. In POLYSIM, world grain markets are assumed to be exogenous to the system, and, primary and secondary impacts of changes in exports or imports cannot be analyzed. Elasticities used in this model can be considered a more subjective approach to reality than observed data, such as costs, yields, and acreage used in other models such as optimization problems.

AGRIMOD[6]

AGRIMOD is a dynamic simulation model of the U.S. food production system that consists of seventeen submodels. The best way to describe AGRIMOD's scope is to trace its 13-step algorithm (Figure B-2). A preparation step is used for setting up the problem and entering exogenous variables.

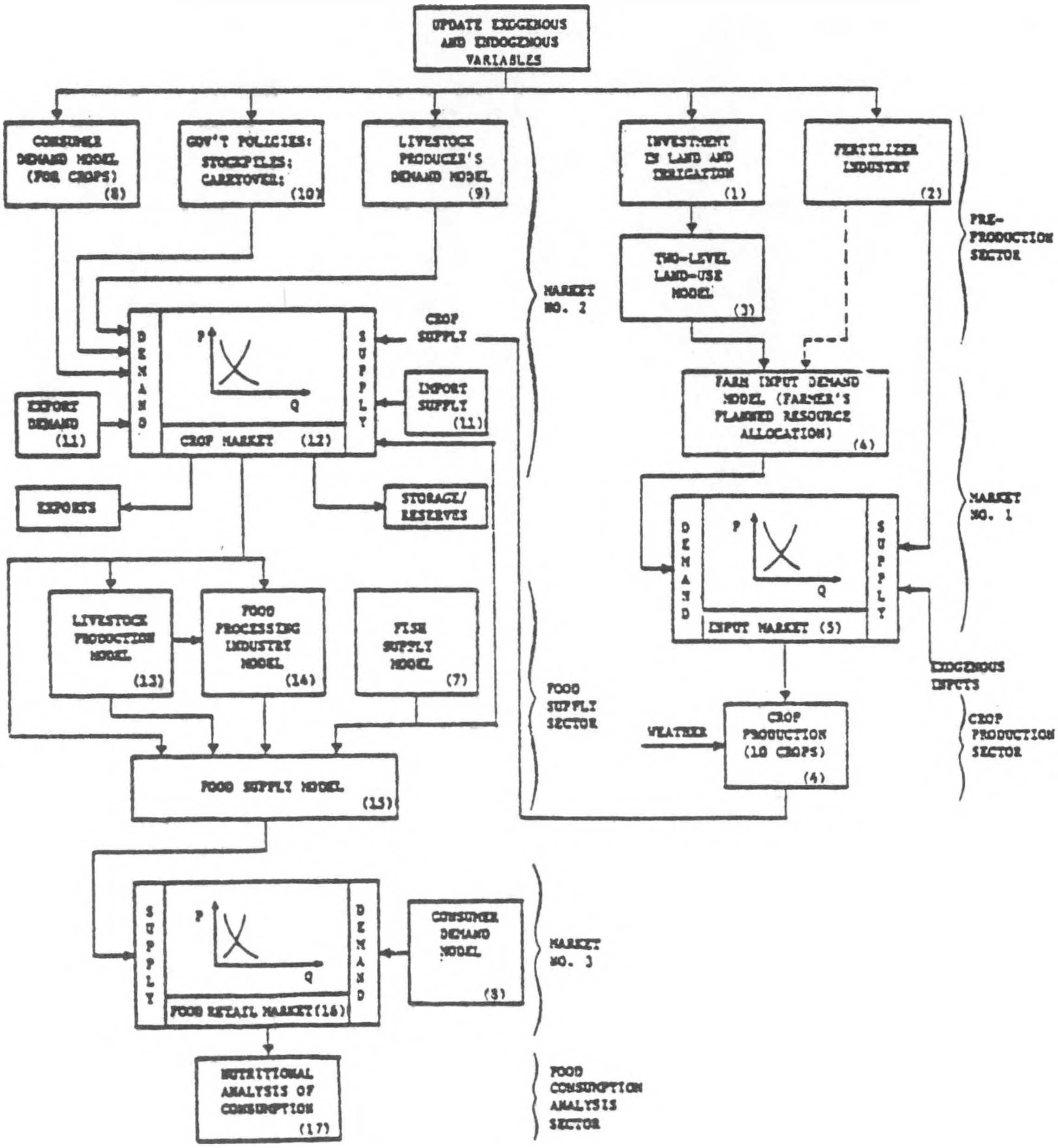


FIGURE B-2. SIMPLIFIED DIAGRAM OF AGRIMOD

Source: AGRIMOD: A Dynamic Simulation Model of the U.S. Food Production System. Part 1 Crop Production, Systems Control, Inc. Palo Alto, California, March, 1977

This step establishes the baseline data for the model. Step 1 constructs a land availability model detailing land development, land policies, and land use. Step 2 calculates the expected prices for crops. The crop producer planning problem, a profit maximization in a perfectly competitive crop producer sector, is formulated and solved in Step 3. Step 4 consists of two models, the farm input market and the fertilizer model. In Step 5, crop yields and production are estimated with corrections for crop losses and stochastic weather effects. Step 6 estimates the consumer food demand impact on demand for crops. Step 7 solves the livestock producer problem for beef, dairy, hogs, and poultry. Step 8 derives the total demand and supply functions for crops. Step 9 solves the price/quantity equilibrium equations of the supply-demand interaction for the ten crop groups. Step 10 initiates the food commodities model with computations of livestock production and derives supply functions for livestock products. Step 11 repeats Step 10 for the crop commodities that can be disaggregated into consumer commodities. Step 12 is a derivation of the price/quantity equilibrium for the food commodities. Step 13 formulates a summarization of the results in terms of average per capita consumption and average per capita expenditures.

AGRIMOD is a highly complex model. If it were to be used to examine the impact of a large scale program to produce alcohol, it would be necessary to change the structure of AGRIMOD. For the sake of a more thorough treatment of some of the important relationships of an alcohol production program, some of the submodels would be deleted--such as the Fish Supply Model or the Nutritional Analysis of Consumption--or the submodels would be restructured to limit the scope to relevant crops or livestock. Some of the variables (especially crops) have little bearing and, therefore, would not be affected by any alcohol production. At the same time it would be necessary to add other descriptive categories to the AGRIMOD database. Distiller's dried grains does not enter the AGRIMOD crop or food commodity classifications. Also, the high degree of complexity within AGRIMOD does not lend itself to the addition of variables.

A linear programming framework has several advantages over the detailed but rather rigid framework of a simulation model such as AGRIMOD:

- Flexibility
- Addition or deletion of variables without changing the basic model structure
- Emphasis optimization statement.

AGRIMOD consists of 17 submodels. Four major sectors and three markets can be distinguished.

(1) The Pre-Production Sector consists of three submodels: the Allocation of Investments, the Management of Land Resources, and the Generation of Supply Curves for Nitrogen, Phosphate and Potash

(2) The Farm Input Market consists of two submodels: the Farm Input Demand Model and a model of the market for non-agricultural inputs to crop production

(3) The Crop Production Sector simply contains functions of crop production

(4) The Crop Market includes: a refinement of the crop production functions with stock and import data, a second modification of the same functions by addition of government policies, the generation from the livestock sector of demand curves for crops, the Retail Food Consumption Model, a first refinement of this last model with foreign demand, and a second refinement with government commitment

(5) The Food Supply Sector consists of four submodels: the Livestock Production Submodel, the Food Processing Industry Model, the Fish Supply Model, and, the Food Supply Model

(6) The Retail Food Market includes an addition to the demand curves for food commodities from consumers and a Food Retail Market Model

(7) The Consumption Analysis Sector is a nutritional analysis of food consumption.

Adjustments in Crop and Livestock Production[5]

The models constructed by Heady and Brokken have been used in studies of adjustments in crop and livestock production. The basic premise of the models is that since livestock feeding accounts for a large portion of the demand for feed grains and oilseed meal, livestock feeding was included in the optimization problem as a means of observing shifts in feed concentrate regional demand. The shifts effect interregional flows of feed grains and oilseed meal, and also could effect the location of production.

The mathematical framework of the models is linear programming. The objective function is minimized subject to a set of constraints. The objectives of the model were to assist in

(1) Analyzing interregional competition and efficient resource allocation for the production of wheat, feed grains, soybeans, cotton, beef, portk, and milk

(2) Determining optimal regional land use and production patterns for these same commodities

(3) Determining changes in production patterns resulting from changes in selected exogenous variables and/or constraints

(4) Determining equilibrium returns to the various categories of land in each region

(5) Determining equilibrium prices for the commodities.

The geographical disaggregation of the model defines 157 crop-producing areas and 20 livestock-producing and product consuming regions. The crop production possibilities correspond to the following commodities or commodity combinations: cotton, wheat, feed grain, feed grain/soybean, feed grain/silage, feed grain/soybeans/silage, hay, hay/silage and wild hay. For the 20 regions of livestock production and product consumption, the agricultural activities defined include: milk cows; beef cows; hogs; yearling feeder calves; plus eight beef-fattening activities. Also, feed supply equations, and demand restraints or equations are part of the model.

Therefore, there are crop producing activities (with the pre-set rotation possibilities of crops), feed transfer activities, livestock producing activities, and transportation activities.

Four types of constraints are quantitatively stated: land constraints, capacity constraints for livestock, exogenous supplies of concentrates and roughages and consumer demand constraints. From these data, three empirical models have been constructed. The first two models: "1954", and "1965", used different levels of crop technology and output requirements; the third model, or Efficient Management model uses a livestock technology corresponding to the most efficient producers. The Efficient Management solution set includes optimal patterns of production and product distribution, levels of crop and livestock production, changes in interregional flow of commodities, cost determinations, and acreage changes.

The Efficient Management study is considered an improvement by its authors over previous studies of the U.S. agricultural sector. The improvement is due largely to the consideration of interdependency for regions and for commodities. It is achieved by adding variables such as forage, hog, beef and dairy production that greatly impact on the production and distribution of previously included variables. The results, however, still are unsatisfactory and unrealistic as can be observed by comparing actual results with the results generated from the model. Over-specialization of land is a questionable output of this study.

Heady improved the model in subsequent studies by not considering geographical areas to be homogenous with respect to production efficiencies, by introducing land quality classes and by increasing the sophistication of the transportation schemes.[4] Even though data gathering for this study required nine man-years for assembly, coefficient calculations are in some cases different for production and consumption. The large quantity of data lends itself to this kind of discrepancy, but it appears that coefficient consistency and correction can be improved.

E.O. Heady, 1979[3], mentioned that he was in the process of looking at the impact of alcohol production from biomass with a submodel of the Iowa Agriculture model that would take a closer look at the price of other forms of energy. Another model will be built to analyze the same program of alcohol production in the U.S. This model will disaggregate the U.S. into 105 or 223 crop producing regions, with 5 land classes. Using the earlier model reviewed here would be ignoring important improvements that will be added to Dr. Heady's series on agriculture modeling.

Economic Aspects of Using Grain Alcohol as a Motor[15] Fuel, with Emphasis on By-Product Feed Markets

Wisner and Gidel's study was a detailed description of the impact of the implementation of six alternative levels of a "gasohol" program on the U.S. agriculture sector. Gasohol was defined as a blend of 10 percent alcohol and 90 percent unleaded gasoline. The six levels of "gasohol" production are "gasohol" (1) used only in Iowa agriculture, (2) used in Iowa for both agriculture and non-agriculture sectors, (3) and (4) used in agriculture and non-agriculture sectors for a 5-state region, and (5) and (6) used in all U.S. agriculture and non-agriculture sectors.

The primary focal point in this study was the potential impact of expanded by-product feed supplies, e.g., what happens when distiller's dried grains compete with soybean meal? Through the consideration of the time lag that would occur in the construction of several fermentation plants, an analysis was conducted for the 1980 and 1985 time frame.

The study began with selected projections and estimates. Potential growth in demand for protein meal in 1980 and 1985 was derived from the USDA projections of demand for livestock and poultry products. This growth in demand was compared with the expected grain supplies for the same period. These steps were repeated for high-protein feeding rates. At that point, alternative sources of supplies for protein feed supply were analyzed for different amounts of alcohol produced from grain.

The results of the model indicated the amount of distiller's dried grains produced from a "gasohol" program for Iowa gasoline projected needs would only have a negligible affect on the price of soybeans and soybean meal. An increased amount of distiller's dried grains from a 5-state region and from the entire U.S. "gasohol" programs places downward pressure on prices.

Estimates of fuel requirements for agricultural and non-agricultural uses were calculated. If gasohol was used to meet these requirements, it would follow that corresponding percentages of the corn crop would be diverted to alcohol use, resulting in increased high-protein feed supplies. Potential export markets for distiller's dried grains were the last consideration in this series of projections.

The mathematical framework of most of the projections was linear regression. When statistical aberrations occurred from past data uses, an average of past years was used for projections. In some cases, fuel for example, projections are made without a specific equation. In those cases, many considerations and assumptions were enumerated.

The study provides an indication of the relationship between distiller's dried grains prices and soybean meal prices. Use of regression analysis, however, fails to capture anticipated or desired changes in the organization of the agriculture sector. In addition, policy changes and optimal resource allocations cannot be analyzed. Even though the livestock and the export markets are included, the study is limited in its reliance on corn for the production of alcohol. Inclusion of other crops cannot be handled reasonably within the framework of this systems analysis study.

The Texas A&M Model[11]

Taylor, et al., developed two linear-programming, spatial-equilibrium models. The models have been used to evaluate boll weevil control strategies and impacts,[12] and to evaluate the national and regional economic impact of hail suppression technologies.[10]

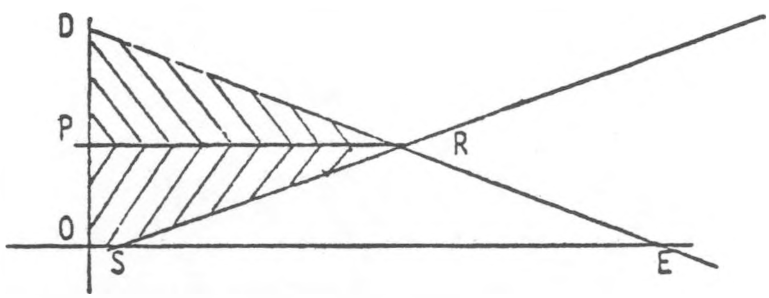
The two models are (1) a cost minimization model, minimizing production and transportation costs for eight commodities, and (2) a consumer's and producer's surplus maximization model for the same commodities.

The surplus maximization model generally is considered to have an advantage compared to the cost model, because it provides a market equilibrium condition and gives a measure of social welfare following a change of conditions such as technology or policy. Social welfare is defined as the sum of consumer's plus producer's surplus.*

Both models give as results the acreage and transportation solutions to meet national demand levels. The surplus model is reviewed here because of its conceptual advantages.

*Footnote

Consumer's surplus is graphically represented by the area above the equilibrium price line and below the demand curve, or the triangle DPR.



It was defined by Alfred Marshall in 1925 as the maximum sum of money a consumer would be willing to pay for a given amount of good, less the amount he actually pays.[7] Producer surplus is graphically represented by the area below the equilibrium price line and above the supply curve or the triangle area OPRS.

The concept of producer's surplus was introduced by Marshall to establish a parallel with consumer's surplus. "When he makes a sale, an individual generally receives something which has a greater direct or indirect utility to him than the utility of the thing he gives up."[2] Both are generally considered to be measures of welfare.

As with most models, the United States has been divided into regions. There are 137 producing regions (with differentiation between irrigated and non-irrigated cropland), and 21 consuming regions. These regions provide cropland constraints and supply-demand balances for each commodity group. Other constraints included cotton lint production, pea production, barge transportation activities, upper and lower flexibility constraints for each production activity, and convex combination constraints for exogenously incorporating the stepped demand functions into the model. Demand functions were not included in the cost model. The use of the model can best be described by examining a study of the national impact of using crop residues and grain to produce alcohol.[13]

In addition to the constraints of the original model a constraint was added for producing a specified amount of alcohol from crops endogenous to the model. Results were an indication of the increase or decrease in prices for feed grains, food grain, oatmeal and cotton lint. Also, the origin of the alcohol is distributed optimally among the different grains and residues, with different distinctions for each level of alcohol produced. The results also include changes in consumer's and producer's surpluses. By disaggregating the United States, it is possible to observe regional impacts of alcohol production. The results indicate regions of increased acreage, changes in transportation patterns and relative profitability for conversion of grains to alcohol.

The Texas A&M Model provides an excellent base for analyzing price movements, production, and transportation pattern changes following the addition of constraints under scrutiny. Some limitations have been defined with the model applications. Of the model's shortcomings, the most difficult to remedy is the necessary assumption of homogeneity of crop production and land use within a producing region. Other shortcomings appear in the definition of constraints. The land constraint includes a harvestable land class but omits the use of current non-cropland, and the definition of consumer's surplus does not account for any surplus that would accrue to consumers of fuel.

The Texas A&M Model has many similarities with the Purdue Model. Both model uses are similar, since both are used to examine impacts of alcohol production and show consistent results. The land inflexibility problem of the Texas A&M Model is the major difference between the two models.[14]

The Purdue Model[1]

As with the Texas A&M Model, the objective of this model was to develop a tool for the analysis of the impact of policy changes on the agricultural sector. Unlike the Texas A&M Model, the Purdue Model linked the American agricultural sector with the world agricultural market and the American non-agricultural market in great detail.

The model was based upon a linear programming framework with the objective function of maximizing consumer's and producer's surplus. The model simulates a competitive equilibrium based on the assumption that the agricultural sector is a perfectly competitive sector. The country is deaggregated into 30 regions, where several primary and secondary commodities are produced. The 208 activities can be broken into field crop production, livestock production, and miscellaneous production. One centrally located market for the whole U.S. was assumed. Marketable goods include all factors (inputs) and all outputs--costs for processing, transportation, and handling were part of production costs which influence the supply of commodities. Only certain commodities were traded and for each of these commodities an excess demand or supply schedule was stated (export or import).

The constraints were grouped into the following categories: market clearing (for agricultural and processed activities for labor, for land and for national inputs), regulations (agricultural production, processing, and input policy restrictions), demand for agricultural commodities (domestic, foreign, and stocks) excess supply (of agricultural commodities), demand for processed commodities (domestic, foreign stocks), excess supply (of processed commodities), and labor and land supply constraints.

The equilibrium prices and quantities for inputs and agricultural and non-agricultural commodities, were determined endogenously subject to the variations imposed on the regulation constraints.

Both the Purdue and the Texas A&M Models were used in a study by Purdue University for the U.S. Congress Office of Technology Assessment (OTA).[14] The purpose of the OTA study was to estimate the impact of producing alcohol from grains and crop residues. Modifications of the Purdue model were necessary for the OTA research: oats, barley, and crop residues (corn, sorghum, small grains, rice and sugarcane) were added as primary commodities. Parallel activities to these commodities were defined, as well as a constraint on the harvestable crop residue, and an increase in the production budget. It also was necessary to develop new animal feeding rations, given that oats, barley, sorghum, and distiller's dried grains can substitute in varying quantities, for corn. It was assumed that distiller's dried grains could be substituted for soybean meal. Two secondary commodities were added, alcohol and distiller's dried grains, with the accompanying processing activities.

As mentioned in the review of the Texas A&M Model, the results provide a reasonable indication of the price changes and the adjustments that would follow in optimal commodities distribution. However, since the Purdue Model is more extensive in its description of the U.S. agricultural sector and its linkages with the non-agricultural sector and the world market, it is easier to follow the scenario of alcohol production through the livestock and the export markets. The Purdue Model also provides a better estimate of the value of crop residue, an important consideration in the production of alcohol from grain.

The relative complexity of the Purdue Model makes it a better tool to describe the agricultural sector. One of the stronger points of the model is the inclusion of the policy restriction constraints. The limits are defined by the policymakers and this feature makes the model more flexible in the context of alcohol production.

Limitations of the model are only minor problems. Because of one centrally located market for the whole U.S., transportation costs were included in the processing activities, which could introduce a bias.

A limited number of commodities were traded, but even with this departure from reality, the commodities relevant to this particular study were included, which can lead to a satisfactory analysis of the impact of an alcohol program on the foreign sector. No accomodation was made for the cost of developing marginal land. Land descriptions by quality and by availability can be improved upon, as well as the substitution rates for feeding rations which prove to be a minor problem in the study of alcohol production from crops.

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(14) Unpublished draft report of a study for the U.S. Congress Office of Technology Assessment, on Energy from Biomass, Purdue University, January, 1979.

(15) Wisner, R.N. and Gidel, J.O., "Economic Aspects of Using Grain Alcohol as a Major Fuel, With Emphasis on By-Product Feed Markets", Economic Report Series, Department of Economics, Iowa State University, June, 1977.

(16) Zeimetz, Kathryn A. "Growing Energy: Land for Biomass Farms", Agricultural Economic Report No. 425, ESCS, U.S. Department of Agriculture, June, 1979.

Supplemental Literature Review

In the process of reviewing existing models of the U.S. agricultural sector, a computer search was initiated. Files of the Commonwealth Agricultural Bureaux Abstracts, the U.S.D.A. Current Research Information System, the National Technical Information Service, the Agricultural On Line Access, and three others were investigated.

Some models were not reviewed in-depth for this study. However, these models should be of interest by providing an understanding of model applications to diverse problems in agriculture, as well as models having a broad scope. The models first discussed are those with economic assumptions or specification closely related to alcohol production from carbohydrate crops. The remainder of the models, while not directly useful for this study, provide the reader with background information.

It should be noted that some of the models described in this Appendix are not yet in final form or are part of a study or project aimed at developing or refining an existing agricultural sector model.

PART 1. Models with material directly relevant to the study of alcohol production from carbohydrate crops.

"Cross Commodity Forecast Modeling", Johnson, J. The annual cross-commodity model has been respecified using a more consistent theoretical structure, an expanded characterization of the foreign sector, additional components for wheat and soybeans and reflecting changes suggested by validation and verification exercises performed on older versions of the model. On-going work includes refinement of the existing annual model including and additional structure for the foreign sector, and more detail to farm income and expenses; estimation and testing of the quarterly model, utilizing the subjective information of commodity specialists to re-estimate, and update previous model estimates; and continued verification and validation exercises emphasizing possibilities for structural change and the application of appropriate variational parameter specifications. The additional work should result in a more diverse and flexible forecasting capability with models more appropriate for outlook and policy analysis.

"Policy Options and Their Impacts on Agriculture", Ray, D.E. An optimization routine was linked to POLYSIM. The optimization routine provides, within a control theory framework, a procedure for selecting policy variables to achieve alternative policy objectives. An alternative policy objective to be maximized is specified as a performance measure that permits trade-offs between farm incomes, government expenditures, and consumer costs. A combined econometric and systems analysis model of the livestock feed economy is being developed. Econometric equations will provide estimates of cow inventories, numbers of calves, veal production, non-fed cattle population, and total feedlot placements. Delay operators and other systems analysis techniques are being used to trace feedlot placements and numbers among specified weight categories. A similar model structure is being developed for hogs. The feed portion of the model is being estimated econometrically.

"Feed Demand in the World GOL Model", Regier, D.W. A mathematical model of the combined world grain-oilseed-livestock (GOL) economy that generates consistent projections of world commodity trade and prices, and regional production and consumption. The model attempts to relate the crop and livestock sectors of agriculture in developed countries. The focus is on the synthesis of feed demand equations containing input-output coefficients and price elasticities sensitive to both livestock products and feeds.

"Alternative Futures for American Agricultural Structure, Policies, Income, Employment, and Exports: A Recursive Simulation", Reynolds, T.M.; Heady, E.O.; Mitchell, D.O. The productive capability of American agriculture is assessed in terms of the ability to satisfy foreign as well as domestic productive requirements. A simulation model of U.S. agriculture describes the behavioral patterns of the agricultural production sector. The simulation model is a national model with submodels for livestock, feed grains, wheat, soybeans, cotton, tobacco, and all other crops. Seven variations of the basic model analyze the impact of alternative farm policies and export levels on American agriculture. From each policy set and assumption about the future, are generated a time series of farm prices, farm income, production, resource demand, etc.

"Estimation of Direct and Cross-Elasticities of Product Supply and Factor Demand", Shumway, C.R. Econometric models will be developed to estimate product supply and factor demand equations for the U.S. Using an existing linear programming model for California, conditionally normative estimates of long-run supply functions for 18 vegetables and field crops will be calculated using parametric programming and regression analysis. Preliminary estimates of the cross elasticities of supply were obtained for six Texas field crops and for twelve U.S. field crops.

"Farm Policy and Rural Income and Employment Models", Sonka, S.T.; Heady, E.O. The major objective of this model is to measure the economic impact of several types of farm programs on the income and employment in rural areas and agriculturally related industries. The quantitative results were estimated by applying a linear programming model to major field crops in the United States. The model, constructed to recognize the land restraints of the important agricultural-producing regions and demand for food requirements in consumer markets, is detailed and permits specification of acreage, crop production, and income in 150 rural areas. Incorporating a transportation network or submodel, into the overall model reflects interregional competition among the agricultural supply and food market areas of the United States.

"Income and Structure of American Agriculture Under Future Alternatives of Farm Size, Policies and Exports", Sonka, S.T.; Heady, E.O. The Model analyzes a major segment of the American agriculture under different future alternatives in 1980 and indicates impacts of the alternatives on variables directly related to farming and the sectors associated with farming. When agricultural exports are projected to follow historic long-run trends, export levels are projected to be higher than those in the late 1960's; however, exports do not exceed recent levels for all farm commodities. Under another hypothesis American agriculture produces at peak capacity with all production in excess of domestic demand being exported. Since consumers are the final beneficiaries of farm production, estimates are made of consumer expenditures for food under various situations.

"Effects of Beef Feeding Practices and Conservation Farming Systems on the Interregional Pattern of Crop and Beef Production", Vock, G.F.; Heady, E.O. In this model on interregional linear programming model of U.S. agriculture analyzes the impact of feeding alternatives for beef cattle in feedlots and of changes in the composition of feed supplies when farming is restrained to reduce soil erosion.

Land in each producing area is brought into crop production under the criterion of minimum cost, i.e., the most productive land is utilized first. This procedure allocates the production of crops and livestock in each of the producing areas to minimize the total production and transportation costs while meeting the demands for agricultural products projected for the year 1985. The model provides a competitive equilibrium since all resources except land receive the market rate of return. Return to land is determined endogenously in the model.

"Cross Commodity Forecast Modeling", Womack, A.W. The econometric models used by the Forecast Support Group of CED have undergone substantial change. The annual cross-commodity model has been respecified using a more consistent theoretical structure, including an expanded characterization of the foreign sector, added components for wheat and soybeans and changes suggested by validation and verification exercises performed on older versions of the model. Work was initiated on the specification and application of a companion model based on quarterly data from the U.S. agricultural sector. On-going work includes the refinement of the existing annual model including additional structure for the foreign sector: estimation and testing of the quarterly model; greater use of commodity specialists information for re-estimating and updating the models.

"Domestic Demand for U.S. Feed Grains: Corn, Sorghum, Oats and Barley, and Econometric Analysis", Womack, A.W. The objective was to build an econometric model that described the economic and non-economic forces associated with demestic feed grain demand. Eleven structural equations were estimated for the annual demand for feed and commercial inventories of maize, sorghum, oats, and barley. A secondary objective was to integrate the equations with independent research in feed grain supply and export demand. A cobweb model was produced for each of the four grains with a total of 25 estimated variables.

Part 2. Important models for the agricultural sector having no direct relevance for the study of alcohol production from carbohydrate crops.

"U.S. Agricultural Export Capabilities Under Various Price Alternatives, Regional Production Variations, and Fertilizer-Use Restrictions", Dvoskin, D.; Heady, E.O. This study is an analysis of United States agricultural products and exporting capacity in 1985 under limited environmental controls of soil loss, fertilizer application, and variations in the flexibility of regional production distribution. The production potential is explored under two pricing assumptions. The first is one approaching the target prices under the Agricultural Act of 1973. The second assumes output that may encourage all-out production by 1985. The linear programming model minimizes the total cost of food production while maximizing the export of agricultural products after meeting prespecified domestic demands. Activities in the model simulate crop rotations, livestock production, water transfer and distribution, commodity transportation, and net export options.

"Energy Use in U.S. Agriculture: An Evaluation of National and Regional Impacts from Alternative Energy Policies", Dvoskin, D.; Heady, E.O.; English, B.C. The time frame for this study in 1985, which provides a time span long enough to premit farmers to respond to the changing energy situation. Under all the alternatives analyzed, the model minimizes the total national cost of crop production, transportation, and agricultural inputs. The cost minimization procedure is subject to a set of primary constraints corresponding to land, water, and energy supplies by regions, production requirements by location, the nature of production, and a final set of commodity supply-demand relationships.

Activities in the model simulate crop rotations, soil conservation and tillage practices, water transfer and distribution, commodity transportation, and nitrogen and energy supplies. Endogeneous crop activities are specified for barley, corn grain, corn silage, cotton, legume hay, non legume hay, oats, sorghum grain, sorghum silage, soybeans, sugar beets, and wheat.

"Grain Marketing and Transportation Interdependencies: A National Model", Fedeler, J.A.; Heady, E.O. Ten specifications of a linear programming model were developed to jointly select the least cost locations of grain production and interregional grain transportation in the United States. Analyses were based on 1980 demand projections for wheat, soybeans, and feed grains. Seven model options represented alternative transportation systems and include alternative estimates of railroad and barge transportation costs. Three other options were specified to analyze interdependencies between grain exports and transportation. The results indicated that choice of transportation mode and grain flows are sensitive to transportation cost changes and the distribution of exports among ports, but the location of grain production is not sensitive to transportation cost changes.

"A World Food Analysis: Grain Supply and Export Capacity of American Agriculture Under Various Production and Consumption Alternatives", Heady, E.O.; Faber, D.C.; Sonka, S.T. It was estimated that increases in U.S. grain exports would be possible in 1980 if any one of three dietary adjustments were made:

(1) Substituting soy protein for 25 percent of the consumer meat consumption

(2) Reducing meat consumption in the United States by 25 percent

(3) Substituting silage for 25 percent of the grain used for producing beef in the United States.

Export possibilities when all of the alternatives are applied simultaneously to the model also were examined. In addition, consideration was given to alternative export possibilities when (1) exports were oriented more toward developed and affluent countries and therefore emphasizing feed grain, and (2) exports were oriented toward poorer nations with large portions of the population undernourished, thereby emphasizing wheat. An auxiliary objective of the analsyis was the application of a linear programming model that permitted crop production (but not water) to be allocated among regions utilizing the comparative advantages of each region for attaining the greatest economic production when considering yields, production costs, and transport costs. The model used assumed a market equilibrium where all factors receive their market price and where production is organized over the nation to minimize production and transportation costs for all commodities.

"An Interregional Analysis of Livestock Use of Selected Feed Ingredients", Kite, R.C. This model concentrates on three aspects of the feed-grain-livestock sectors: the regional location of feed-grain supplies, regional requirements for livestock and poultry feeds and, requirements for grain exports and soybean meal. A national interregional linear programming model is used and utilizes interdependencies between the feed-grain and livestock sectors. The model is intended to be flexible enough for analysis of broader agricultural policy issues.

"Direct Economic Effects of Increased Energy Prices on Corn and Soybean Production on Cash Grain Farms in Southeastern Michigan", Lehrmann, J.A., Black, J.R., Connor, L.J. A linear programming model was utilized to obtain the optimal combination of maize and soybean enterprises which maximize farm profits, subject to certain resource constraints. Sensitivity analysis was used to determine the effects ln crop mix caused by: (1) increasing soybean to maize price ratio, and (2) energy prices. Given constant energy prices and maize prices, as soybean prices increase, maize acreage decreases and operating income increases.

"American Agriculture in 1980 Under Alternative Levels of Crop Exports and Fertilizer Usage", Thomas D.L. Using a linear programming model which minimized production and transportation costs of the endogenous crops, 11 alternatives of American agriculture in 1980 were investigated.

The alternatives were differentiated by fertilization level and export levels of wheat, maize, and oilmeals. The following variables were discussed, endogeneous crop production and acerage location, national supply prices for endogenous crops and livestock, national fertilizer usage, consumer food costs, and net farm incomes for various endogenous crops.

"Alternative Crop Exports and Fertilizer Restrictions in 1980: Effects on Farm Prices, Food Costs, and Farm Income", Thomas, D.L., Heady, E.O. The major objective of this model was to examine the possible effects of fertilizer rates and alternative export levels on the production and prices of U.S. agriculture in 1980. Another objective was to examine the effects of various fertilizer and export levels on the livestock industry and consumer food costs. Two auxiliary objectives also included were (1) the determination of crop production capacity of the United States possible under two fertilizer levels that would not seriously depress the livestock economy; (2) the estimation of fertilizer demand for different crops when production is optimally allocated among producing areas. The study analyzed production possibilities in 1980 if land were allocated in the best manner among crops and regions.

A complete citation for the models described above follows.

Johnson, J., "Cross Commodity Forecast Modeling", Project No. CE-10-090-29, Commodity Economics Division, ERS, University of Missouri (December 1976 to December, 1978).

Ray, D.E., "Policy Options and Their Impacts on Agriculture", Project No. OKL01612, Agricultural Economics Department, Oklahoma State University (July, 1975 to June, 1980).

Regier, D.W., "Feed Demand in the World GOL Model", Agricultural Economics Research, USDA, ESCS (1978).

Reynolds, T.M.; Heady, E.O.; Mitchell, D.O., "Alternative Futures for American Agricultural Structure, Policies, Income, Employment, and Exports: A Recursive Simulation", CARD Report No. 56, Iowa State University (1975).

Shumway, C.R.; Beattie, B.R., "Estimation of Direct and Cross-Elasticities of Product Supply and Factor Demand", Project No. TEX06144, Agricultural Economics Department, Texas A&M University (February, 1975 to February, 1980).

Sonka, S.T.; Heady, E.O., "Farm Policy and Rural Income and Employment Models", Chapter 8 in "Spatial Sector Programming Models in Agriculture", Iowa State University (1975).

Sonka, S.T.; Heady, E.O., "Income and Structure of American Agriculture Under Future Alternatives of Farm Size, Policies and Exports", Report No. 53, Iowa State University (1975).

Vocke, G.F.; Heady, E.O., "Effects of Beef Feeding Practices and Conservation Farming Systems on the Interregional Pattern of Crop and Beef Production", CARD Report No. 79, Iowa State University (1978).

Womack, A.W., "Cross Commodity Forecast Modeling", General Research Area, USDA, ERS (July, 1975 to October, 1983).

Womack, A.W., "Domestic Demand for U.S. Feed Grains: Corn, Sorghum, Oats and Barley, An Econometric Analysis", Dissertation, University of Minnesota (1976).

Dvoskin, D.; Heady, E.O., "U.S. Agricultural Export Capabilities Under Various Price Alternatives, Regional Production Variations, and Fertilizer Use Restrictions", CARD Report No. 63, Iowa State University (1975).

Fedeler, J.A.; Heady, E.O., "Grain Marketing and Transportation Interdependencies: a National Model", American Journal of Agricultural Economics, Volume 58, No. 2 (1976).

Heady, E.O.; Faber, D.C.; Sonka, S.T., "A World Food Analysis: Grain Supply and Export Capacity of American Agriculture Under Various Production and Consumption Alternatives", CARD Report No. 60, Iowa State University (1975).

Kite, R.C., "An Interregional Analysis of Livestock Use of Selected Feed Ingredients", Dissertation, Purdue University (1973).

Lehrmann, J.A.; Black, J.R.; Connor, L.J., "Direct Economic Effects of Increased Energy Prices on Corn and Soybean Production on Cash Grain Farms in Southeastern Michigan", Agriculture Economics Report, Michigan State University (1976).

Thomas, D.L., "American Agriculture in 1980 Under Alternative Levels of Crop Exports and Fertilizer Usage", Dissertation, Iowa State University (1976).

APPENDIX C

List of Basic Data Sources

This appendix contains basic information concerning the sources of the data, and justifications for some of the computations.

Geographical Region - Area of Relevance

The Corn Belt Region (Illinois, Indiana, Iowa, Missouri, Ohio) is used in the model. The impact of using food and feed crops for fuel production is expected to be the greatest in this area where agriculture is one of the most important industries.

All quantities are calculated for this region only and results cannot be transferred to another region.

Many sources publish data information by states and also by regions. Within a region there exists some homogeneity for important variables, which are useful in constructing the model, such as type of crops and livestock, soil, and cost of production items.

Crop Production

Only the major crops growing in this area were included in the linear programming analysis:

They include:

- Corn
- Soybeans
- Wheat
- Grain Sorghum
- Oats
- Alfalfa

To establish the importance due to each of these crops over a substantial length of time, data was collected on quantities produced, used on the farm and sold for a 10-year period from 1967-1977. Quantities were collected by states and aggregated for the region. Data for 1967 and 1977 are shown in Table C-1.

Selling Price of Crops

To establish a market value for the crops, two assumptions were made.

(1) Price of crop sold. The value was a volume weighted average of price received by the farmer the preceeding season. Farmers make management decisions based on the expected price for one season. It was therefore assumed that at a time "t" the farmer would consider his crop to be valued at a price "P" $P_t = P_t-1$

(2) Price of crop used on farm. It was assumed that the portion of the crops which is kept for the farmer's use would in fact go through no marketing process and would have a value to the farmer equal to its full cost.

Battelle used two sources for the price and cost data:

- USDA Agricultural Statistics 1969-1978.
- FEDS, Commodity Economics Division, DSCS, Oklahoma State University, Stillwater Oklahome. Year 1977, printed 11/8/78.

Fertilizer Requirements

Fertilizer data was calculated from bulletins obtained from the Firm Enterprise Data System, the Commodity Economics Division, ESCS, Oklahoma State University. To obtain data valid for the region, quantities used in each area of each state were measured. 1977 was used because it was the latest revised data available.

Cropland Available

Agriculture production will be ultimately limited by the amount

TABLE C-1. QUANTITY OF SELECTED CROPS USED ON FARM AND SOLD IN U.S. CORN BELT, 1967 AND 1977.

		CORN 1 million bu	SOYBEAN 1 million bu	WHEAT 1 million bu	OATS 1 million bu	ALFALFA 1 million tons	GRAIN SORGHUM 1 million bu
1967	USED ON FARM	1,296	14	18	129	19	10
	SOLD	1,662	513.5	207	63	2	8.5
1977	USED ON FARM	1,230	12.4	21	93	20	32
	SOLD	2,241	988.3	247.5	50	3	43.5

Source: Agricultural Statistics, USDA, 1968, 1978 and Battelle Calculations.

of land available. Acreage available by class was obtained from "Growing Energy, Land For Biomass Farms" Kathryn A. Zeimetz, USDA ESCS, Agricultural Economic Report No. 425, June, 1979 and the National Summary Table 13, 1977 SCS National Erosion Inventory Estimates (December 1978).

Cost, Yield Per Acre

Cost per acre of crop production and yield per acre, were obtained, for 1977 from the Firm Enterprise Data System, Commodity Economics Division, ESCS, Oklahoma State University, Stillwater, Oklahoma, Published 11/79.

Alcohol, Carbohydrate, and Protein Content of Crops

Each crop yields a given amount of alcohol, carbohydrates, and protein. This information was calculated from data obtained from the Handbook of Nutritional Content of Foods, USDA, quoted in Fuel From Farms, Solar Energy Research Institute, Midwest Research Institute, February, 1980.

The amount of alcohol obtained from sweet sorghum was the amount observed during Battelle experiments.

Amount of Alcohol Obtained from Agricultural Crops

Corn	2.6 GA/Bu
Soybean	0
Wheat	2.3 Ga/Bu
Oats	0
Alfalfa	0
Grain Sorghum	2.6 Ga/Bu
Sweet Sorghum	11.7 Ga/Ton (wet basis)

Percentage of Protein and Carbohydrates in Crops
Included in the Model

	Carbohydrate	Protein
Corn	33.5	34.1
Soybean	72.1	10.2
Wheat	44.6	11.6
Oats	25.4	17.7
Alfalfa (Sugars and Cellulose)	70.4	10.4
Grain Sorghum	72.2	8.9

Weight Equivalents

For the purpose of this study, the following weight equivalents have been used.

Corn	70 lb/Bu
Oats	32 lb/Bu
Sorghum, grain	56 lb/Bu
Soybeans	60 lb/Bu
Wheat	60 lb/Bu

Yield, Cost, And Fertilizer By Land Type By Crop

The following data was calculated for use in the model: yield per acre, production cost per unit, and fertilizer requirements in pounds per acre for each crop and for each land type. The method of obtaining the data is described in the text.

Corn--bushels

Land Type	Yield	Cost/Bu	Nitrogen	Phosphate	Potash
1	119.1	2.20	113.6	80.1	98.9
2	97.0	2.10	126.1	74.6	88.4
3	77.6	2.20	124.0	46.2	48.0
4	60.4	2.57	121.3	50.2	47.6
5	119.1	2.93	151.5	106.8	131.9
6	87.3	2.87	166.7	80.5	90.9

Soybeans--bushels

Land Type	Yield	Cost/Bu	Nitrogen	Phosphate	Potash
1	40.67	4.90	9.7	0.0	16.1
2	35.62	4.90	3.1	11.0	15.1
3	31.22	5.10	4.9	13.0	16.1
4	27.31	5.95	1.1	8.3	12.2
5	40.67	6.53	12.9	0.0	21.5
6	33.42	6.67	5.3	16.0	20.8

Oats--bushels

Land Type	Yield	Cost/Bu	Nitrogen	Phosphate	Potash
1	64.34	1.50	10.2	20.8	21.2
2	53.91	1.60	10.2	20.8	21.2
3	47.57	1.70	9.1	12.8	12.6
4	40.63	1.98	5.0	10.0	10.0
5	64.34	2.00	13.6	27.7	28.3
6	50.74	2.20	12.9	22.4	22.5

Wheat--bushels

Land Type	Yield	Cost/Bu	Nitrogen	Phosphate	Potash
1	47.62	2.50	58.3	62.8	55.4
2	40.72	2.60	54.3	52.9	49.8
3	34.68	2.80	58.8	42.1	43.9
4	29.33	3.27	19.5	25.3	12.5
5	47.62	3.33	77.7	83.7	73.9
6	37.70	3.60	75.7	63.3	62.5

Alfalfa--tons

Land Type	Yield	Cost/Ton	Nitrogen	Phosphate	Potash
1	3.83	44.30	11.6	31.2	76.5
2	3.23	44.40	11.6	31.2	76.5
3	2.71	50.60	13.3	46.7	78.3
4	2.24	59.03	13.3	46.7	78.3
5	3.83	59.07	15.5	41.6	102.0
6	2.97	63.33	16.6	51.9	103.2

Grain Sorghum--bushels

Land Type	Yield	Cost/Bu	Nitrogen	Phosphate	Potash
2	78.0	1.90	73.0	30.0	28.0
3	65.0	2.10	73.0	30.0	28.0
4	52.0	2.45	73.0	30.0	28.0
6	71.5	2.67	97.3	40.0	37.3

Sweet Sorghum--tons

Land Type	Yield	Cost	Nitrogen	Phosphate	Potash
1-4	See Table 3	$243/acre*	75.0	85.0	97.0

* Unit cost will fall as yields increase over time

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