An economic study of the beet sugar industry in Montana--a regional analysis
by Willard Horace Godfrey

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Agricultural Economics
Montana State University

Abstract:
The sugar beet and sugar cane industry in the United States produces approximately 40 percent of domestic annual consumption. Sixty percent of the United States' sugar supplies are imported from off mainland sources as well as foreign countries. This situation places the U.S. in a precarious position should foreign sugar supplies be restricted from the domestic market for one reason or another.

Because Montana supplies 6.4 percent of domestic sugar demands any change in the world or domestic market channels affecting the U.S. will also influence the Montana sugar industry. The problem of this research was to estimate potential Montana sugar supplies at alternative beet prices for 1980.

Five sugar beet production regions in Montana were examined. A variable price linear programming model was used to ascertain collective farmer production response. Two basic models were developed for each region. One was a regional model and the other a typical farm analysis.

The results of the analysis suggest that sugar beet production in the specified regions could be expanded from the present 65,000 to between 127,000 and 184,000 acres at $17.50 per ton (projected 1980 price). These responses are probable if government controls are not restricting, if all producers have an equal desire to grow sugar beets, and if sugar refinery capacity is unlimited.

Regional and typical farm responses were compared. The regional model estimates are smaller than similar estimates made from aggregating benchmark farm responses. The decision to use a regional or typical farm as the responding unit in future research is dependent upon the amount of information needed about an individual group of producers and their response to economic stimuli. Regional models result in aggregate supply estimates at a low research cost that may serve for policy decisions just as well as alternative methods of measuring production response.

There are three sugar factories in Montana and all are expected to be enlarged by 1980 to an aggregate slicing capacity of 13,500 tons per day. Other ways of expanding Montana's capacity of manufacturers' sugar are (1) adding a new factory, (2) storing thick sugar juices for future processing, and (3) increasing the storage life of the sugar beet.

AN ECONOMIC STUDY OF THE BEET SUGAR INDUSTRY IN MONTANA - A REGIONAL ANALYSIS

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Willard Horace Godfrey, Jr.

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

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in

Agricultural Economics

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ABSTRACT

The sugar beet and sugar cane industry in the United States produces approximately 40 percent of domestic annual consumption. Sixty percent of the United States' sugar supplies are imported from off mainland sources as well as foreign countries. This situation places the U.S. in a precarious position should foreign sugar supplies be restricted from the domestic market for one reason or another.

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CHAPTER I

INTRODUCTION

Sugar or shurkara, as it was initially found in the ancient writings of the Hindus of India, referred to those substances sweet to the taste. Sugar, a white or colorless crystal when purified, constitutes a major ingredient in the diet of many people in the world.

The group of compounds called sugars are more generally classified as carbohydrates. There are two basic groups of sugars, glucose or monoses ($C_6H_{12}O_6$) and saccharoses or bioses ($C_{12}H_{22}O_{11}$). Glucose is referred to as grape sugar whereas saccharoses is more commonly called cane sugar. 1/ The latter group (saccharoses) is of importance in this research because it represents the primary source of sucrose.

Sucrose and lactose (milk sugar) are the chief constituents of the cane sugar group. The main sources of sucrose sugar are sugar beets, sugar cane, sugar maple, and sugar palm. 2/ Sugar cane and sugar beets account for the major portion of world sugar supplies.

Oliver de Serres, a french agronomist, discovered in 1705 that beet roots contained sugar. However, it was not until 1755 that Marggrof, a Prussian chemist, obtained sugar crystals from a beet through

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1/ John Geddes McIntosh, The Technology of Sugar, New York; D. Van Nostrand Company, 1903, pp. 1-2.

2/ Ibid., pp. 1-2.

experimental procedures and proceeded to exploit the discovery. 3/ Achaid, a student of Marggraf, invented and perfected a method for commercially extracting sugar from beets in 1799. His small factory at Cunern, Silesia, is considered to be the first commercially oriented beet sugar processing plant. 4/

Sugar from cane is reported to have been used in a crude form in China during the year 760 B. C. 5/ Explorers introduced sugar cane to North America in 1493 and to the United States (Louisiana) in 1751. 6/

World Sugar Production

Sugar cane production is limited mostly to those countries lying in a region between 35 degrees north latitude and 35 degrees south latitude. Sugar beet production is found mostly in the United States and Europe located as far as 50 degrees north latitude (Figure 1). A small part of world sugar beet production is located outside these areas.

3/ Harry A. Austin, History and Development of the Beet Sugar Industry, Washington, D. C., United States Beet Sugar Association, 1928, pp. 11-12.

4/ Ibid., pp. 11-12.

5/ W. G. Taggart and E. C. Simon, "A Brief Discussion of the History of Sugar Cane: Its Culture, Breeding, Harvesting, Manufacturing, and Products", Louisiana State Department of Agriculture and Immigration (Fourth Edition), 1939, pp. 1-20.

6, John H. Martin and Warren H. Leonard, Principles of Field Crop Production, New York, The Macmillan Company, 1955, p. 438.

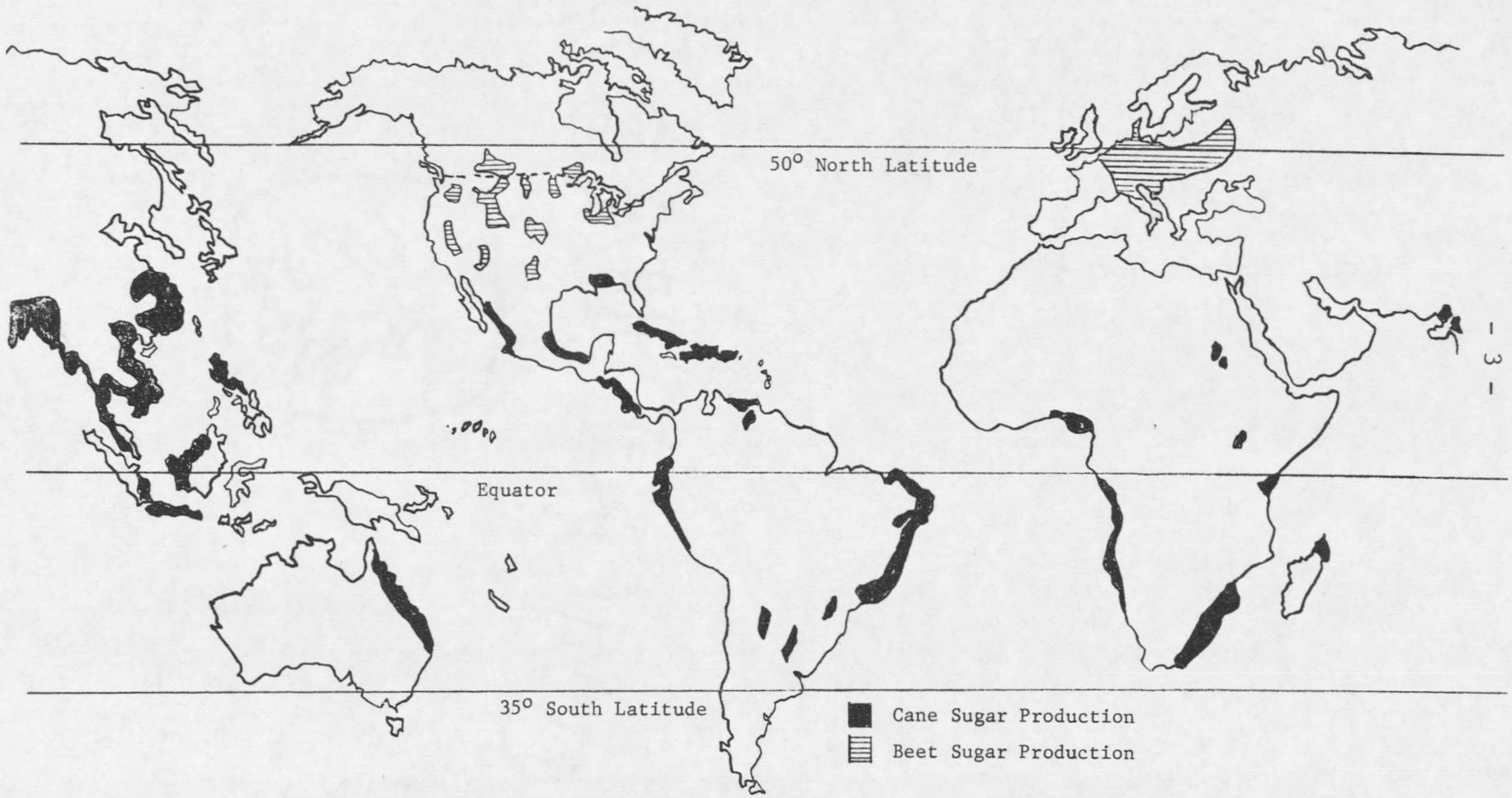

Figure 1. Location of World Sugar Beet and Sugar Cane Producing Areas.

The average annual world production of centrifugal sugar from 1960 through 1966 was 60.9 million short tons. 7/ 8/ The projected 1967-68 world centrifugal sugar production is nearly 72 million short tons. 9/ Cuba is the largest North American producer of sugar followed by the United States and Mexico. The Foreign Agricultural Service estimates that 1968 North American sugar production will be 17.2 million short tons, a 5 percent decrease from 1966-67. 10/ The United States sugar industry accounted for an average of 27 percent of world sugar production between 1960 and 1967. Asia and Western Europe followed with 16 and 15 percent respectively.

According to recent reports, the production of sugar in 1968 in Asia, Western Europe, and Russia is expected to increase while in the United States, production is estimated to decrease. 11/ These reports indicate that sugar production in Asia will increase 16.6 percent while

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7/ Centrifugal and non-centrifugal are names given to sugars based on the method of refining. The difference between the two methods of refining is dependent on the way that impurities are removed from sugar juices.

8/ Sugar ton measurement generally used in the United States is referred to as a short ton or 2,000 pounds. Great Britain commonly uses the long ton measurement or 2,240 pounds.

9/ United States Department of Agriculture, Foreign Agricultural Service Foreign Agricultural Circular, Sugar, FS 4-67, Washington, D. C., December 1967, pp. 10-11.

10/ Ibid., pp. 10-11.

11/ Ibid., pp. 10-11.

United States production will fall 24 percent. In fact, all major sugar producing countries in North America are expected to have diminished absolute production in 1968.

United States Sugar Production

An attempt was made in the United States to grow sugar beets and extract sugar for domestic use in 1836. The first beet sugar refinery was established at Northampton, Massachusetts, in 1838. 12/ Cane sugar, however, was first refined in the United States in Louisiana in 1791.

The sugar industry in the United States has continued to expand since the early attempts to grow cane and sugar beets for the purpose of extracting sugar for domestic use. Beet sugar production is currently found in 18 states (Table I). Cane sugar is produced mostly in Louisiana and Florida. However, cane growers in Georgia, Alabama, and Texas produce sugar cane for syrup. 13/

The beet sugar industry of the United States included 60 refining factories in 1967. 14/ Colorado and California account for 22 factories and 35 percent of all refining capacity in the United States. There were three sugar refining factories located in Montana in 1967.

12/ Austin, op. cit., p. 17.

13/ Martin, op. cit., p. 437.

14/ United States Beet Sugar Association, American Beet Sugar Companies, 1967-1968, Washington, D. C., p. 5.

TABLE I. BEET SUGAR PRODUCTION IN THE UNITED STATES 1967. a/

State	1967 (Cwt. Refined)	Percent of Total
California	10,290,720	20.5
Colorado	7,780,841	15.5
Idaho	5,965,837	11.9
Minnesota	3,814,006	7.6
Montana	3,217,765	6.4
Michigan	2,861,937	5.7
Washington	2,809,554	5.6
Oregon	2,291,747	4.6
Wyoming	2,184,938	4.3
Nebraska	2,125,020	4.2
Texas	1,576,423	3.1
Utah	1,462,287	2.8
North Dakota	1,341,353	2.7
Ohio	1,256,655	2.5
Iowa	577,786	1.1
Arizona	560,000	1.1
Maine	112,207	.2
New York	78,195	.2
Total	50,307,253	100.0

a/ Source: United States Beet Sugar Association, Washington, D. C., March 13, 1968.

Montana Sugar Production

The production of sugar beets in Montana dates back to 1898. 15/ Research at Montana State University by F. W. Traphagen concerning the feasibility of sugar beet production in Montana was considered to be a motivating force behind the establishment of the sugar industry in the state.

The sugar beet producing areas in Montana are in regions where irrigation water is available and where the growing season is 95 or more days. Beets are adapted to a wide variety of soil types throughout the irrigated valleys of the state.

Sugar beets are currently being grown in 16 of the 56 counties in Montana. Other irrigated areas representing 13 additional counties no longer support a sugar beet crop because the growing season is too short and because the cost of shipping beets long distances to refining factories is too high. 16/

The production of sugar beets in Montana has varied over the last 20 years. During 1947, 77,000 acres of sugar beets were harvested. Twenty years later, 57,200 acres of sugar beets were harvested (Table II).

15/ F. W. Traphagen, The Sugar Beet in Montana, Montana Agricultural Experiment Station, Bulletin No. 19, Bozeman, Montana, October 1898.

16/ Sugar beets are currently grown in the following Montana counties: Stillwater, Yellowstone, Carbon, Big Horn, Rosebud, Treasure, Custer, Dawson, Prairie, Richland, Phillips, Blaine, Broadwater, Ravalli, Missoula, and Lewis and Clark. Sugar beets were formerly grown in Jefferson, Madison, Hill, Cascade, McCone, Valley, Teton, Powder River, Sweet Grass, Gallatin, Lake, Sanders, and Pondera counties of Montana.

TABLE II. MONTANA SUGAR BEET PRODUCTION: ACRES PLANTED, ACRES HARVESTED, YIELD PER ACRE AND TOTAL PRODUCTION, ALTERNATE YEARS 1929-1967. a/

Year	Total Acres Planted (000)	Total Acres Harvested (000)	Average Yield per Acre (Tons)	Total Production (Tons)
1929	41.0	38.0	10.2	386,000
1931	59.0	54.0	11.4	617,000
1933	71.0	68.0	12.3	838,000
1935	53.0	51.0	11.2	570,000
1937	76.0	70.0	12.2	852,000
1939	77.0	74.0	12.1	894,000
1941	66.0	64.0	12.4	793,000
1943	60.0	57.0	10.2	581,000
1945	87.0	81.0	10.7	865,000
1947	82.0	77.0	11.7	899,000
1949	65.0	59.0	11.8	697,000
1951	48.8	44.9	12.0	538,800
1953	45.3	43.6	13.4	586,000
1955	50.8	50.0	14.5	724,000
1957	57.9	56.8	15.7	891,000
1959	57.7	52.6	15.7	827,000
1961	68.2	60.6	14.7	893,000
1963	66.7	65.7	17.8	1,170,000
1965	62.2	60.5	12.4	748,000
1967	59.5	57.2	17.6	1,013,760

a/ Source: United States Department of Agriculture Statistical Reporting Service, Montana Agricultural Statistics, Helena, Montana.

Not only have the number of acres planted and harvested varied, but also the yield per acre has fluctuated from 10.2 tons in 1943 to 17.8 tons per acre in 1963. 17/ During the 1966-67 sugar campaign, Montana growers

17/ Acres planted often differ from acres harvested because of adverse conditions that exist during the growing season. Hailstorms, wind, water shortage, improper weeding, and poor seeding are among the factors that lead to the abandonment of planted sugar beet acreage.

averaged 17.6 tons of sugar beets per acre. Even though the number of acres of sugar beets harvested is declining, total production is increasing due to the higher yields experienced by Montana growers.

Sugar beets in Montana are processed for sugar by two refining companies--the Holly Sugar Company and the Great Western Sugar Company. The Holly Sugar Company has two refining plants, one located at Sidney and the other at Hardin. The Great Western Sugar Company refinery is located at Billings. 18/ The combined capacity of these plants is 8,400 tons of sugar beets sliced per 24-hour day. 19/

World Sugar Consumption

Sugar is considered to be the most economical and most easily consumed body fuel. 20/ According to Silin, carbohydrates, which include sugar and starch, are the chief sources of energy for the human body. 21/ Sugars, unlike starch, are assimulated immediately by the body after intake. However, the body is unable to draw its total source of energy from sugar alone. A slow but constant flow of energy from starch is also required. It has been recommended that

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18/ Great Western Sugar Company recently became a subsidiary of the Great Western United Corporation.

19/ United States Beet Sugar Association, op. cit., p. 5.

20/ P. M. Silin, Technology of Beet-Sugar Production and Refining, United States Department of Agriculture and the National Science Foundation, Washington, D. C., 1964, p. 2.

21/ Ibid., p. 3.

sucrose should not exceed 25 percent of the total carbohydrate body requirement. 22/ Nevertheless, because of its nutritional, organoleptic, and physical properties, sucrose is considered to be an indispensible food product. 23/

The overall consumption of sugar is dependent on the size of the population, tastes and preferences, price of substitute sweeteners, price of sugar, and disposable personal income of consumers. According to Viton and Pegnolosa of the United Nations Food and Agricultural Organization (FAO), differences in sugar consumption are mostly dependent upon income. 24/ As expected, the income elasticity for sugar in low income countries is higher than in high income countries.

World sugar consumption increased 86.5 percent from 1953 to 1967. In 1953, 35.2 million metric tons of raw sugar 25/ were consumed, compared to 65.7 million metric tons of sugar consumed in 1967. 26/

22/ Ibid., p. 3.

23/ Austin, op. cit., p. 7.

24/ A. Viton and F. Pegnalosa, "Trends and Prospects in World Sugar Consumption", Monthly Bulletin of Agricultural Economics and Statistics, Vol. IX, Nos. 1 and 2, FAO, Rome, Italy, 1960.

25/ A metric ton is 2204.6 pounds. Raw value sugar or raw sugar refers to the pure syrup extract from sugar cane and sugar beets. Once impurities are removed the sugar is put into a crystalline form and, for all practical purposes, considered pure.

26/ Lamborne Sugar-Market Report (Weekly), New York, August 22, 1967.

Over the same period, world population increased 35.8 percent. Again, it is reasonable to expect future demand for sugar to respond to population and income changes.

United States Sugar Consumption

Sugar consumed in the United States comes from the following four sources: (1) domestic sugar beets, (2) domestic sugar cane, (3) off mainland cane, and (4) foreign sugar beets and cane. Sugar for domestic consumption, produced by the domestic beet and cane industries, represents 41 percent of the total 1967 United States requirements. An additional 18 percent of domestic requirements originates in Hawaii, Puerto Rico, and the Virgin Islands. Fifty-nine percent, or 6.3 million short tons, of raw sugar was supplied by domestic and off mainland cane and sugar beet growers in 1967. 27/ The balance, 4.4 million short tons or 41 percent, was imported from foreign sources (Table III).

The per capita consumption of sugar in the United States has remained fairly stable over the last 20 years. In 1947, per capita consumption was 95.5 pounds compared to 97.4 pounds in 1966. The range in per capita consumption varied from 94 pounds in 1948 to 100.6

27/ United States Department of Agriculture Release, U.S.D.A. Announces Increase in Sugar Quota, No. 324-67, Washington, D. C., February 2, 1967.

TABLE III. TOTAL SUGAR QUOTAS AND PRORATIONS AS GRANTED BY THE UNITED STATES GOVERNMENT FOR DOMESTIC SUGAR SUPPLY 1967. a/

Production Area	Quota in Short Tons
Domestic Beet Sugar	3,215,667
Mainland Cane Sugar	1,169,333
Hawaii	1,252,543
Puerto Rico	725,000
Total Domestic	6,362,543
Philippines	1,126,020
Argentina	63,064
Australia	190,539
Bolivia	6,102
Brazil	512,651
British Honduras	13,378
British West Indies	183,641
Republic of China	79,391
Columbia	54,250
Costa Rica	60,357
Dominican Republic	618,131
Ecuador	74,591
El Salvador	37,301
Fiji Islands	41,813
French West Indies	57,767
Guatamala	50,863
Haiti	28,480
Honduras	6,085
India	76,216
Ireland	5,351
Malagasy Republic	8,997
Mauritius	17,466
Mexico	524,181
Nicaragua	52,889
Panama	32,815
Peru	408,901
South Africa	56,103
Swaziland	6,881
Thailand	17,466
Venezuela	25,767
Foreign Total	4,437,457
Grand Total	10,800,000

a/ Source: U.S.D.A., A.S.C.S., Sugar Report, No. 187, Washington, D. C., December 1967, p. 22.

pounds in 1950. 28/ The Lamborne Marketing Service estimated that per capita consumption of sugar in 1967 would decrease to 95.9 pounds. 29/

In summary, world sugar supplies amounted to 72 million metric tons in 1967. World sugar consumption was estimated at 65.7 million metric tons for the same time period. Of those countries producing sucrose sugar, 30 were directly responsible for 41 percent of the United States needs. Hawaii, Puerto Rico, and the Virgin Islands accounted for an additional 18.3 percent of the United States' sugar demand in 1967. Therefore, domestic sugar beet and sugar cane growers only supplied 40.7 percent of the United States' sugar needs in 1967.

Problem

There are a number of factors that can affect the demand of sugar in the United States. Among these factors are technology, foreign and domestic crop failures, disagreements with exporting countries, changes in tariff and trade agreements, modifications in domestic sugar policy and legislation, as well as changes in population, prices, disposable income, and tastes and preferences.

As historical data illustrates, the United States has depended on foreign countries as well as off mainland sources to supply approximately

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28/ United States Department of Agriculture, Agricultural Statistics 1967, Washington, D. C., 1967, p. 106.

29/ Lamborne Sugar-Market Report, (Weekly), New York, February 21, 1966, p. 2.

60 percent of domestic sugar supplies. This situation currently exists and places the United States in a precarious position.

The potential for sugar supply problems in the United States arises if relationships with exporting countries falter or are discontinued due to foreign control of shipping lanes. The United States experienced a shortlived sugar crises in 1962 when diplomatic and trade relations were discontinued with Cuba. The impact on the domestic sugar industry resulted from a reduction of three million tons of sugar exported annually to the United States by Cuba. 30/ Other foreign countries as well as the domestic beet and cane sugar industries eventually were allocated Cuba's 3,000-ton quota. Similar disagreements could temporarily impair domestic sugar supplies depending on the response of mainland cane and sugar beet growers to adjust to changes in demand. It may be possible for the domestic sugar industry to expand production in order to offset any foreign sugar supply reductions. However, little is known concerning the response of producers to price variations.

There are other potential domestic sugar supply problems. If United States trade relations with sugar exporting countries continue according to agreements made under the 1967 Sugar Act, there is a question as to whether domestic sugar production, both cane and beet

30/ Special Study on Sugar, A Report of the Special Study Group on Sugar of the United States Department of Agriculture, Washington, D. C., February 17, 1961, p. 19.

sugar, can be expanded to meet a growing United States demand. Also, it is imperative to determine if production could be reduced and under what conditions.

Because the sugar industry in the United States is affected by changes in world sugar marketing, a study was needed that would indicate where sugar industry expansion or contraction would take place and under what conditions changes would be made. Such a study was initiated in 1963 by the directors of the Western Agricultural Economics Research Council. 31/ Four objectives were established. One of these objectives was to assess the capacity of domestic and foreign sugar industries to respond to changes in demand. This study represents the Montana Agricultural Experiment Station contribution to this objective.

Because Montana sugar beet growers produce 6.4 percent of domestic sugar supplies it is reasonable to expect that any changes made in the domestic sugar program would affect the sugar industry within Montana. It is hypothesized that the beet sugar industry in Montana (farmers and sugar refining companies) is operating at something less than full capacity and hence will be able to expand supplies of beet sugar beyond existing production by drawing from potential sugar beet producing

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31/ This study is being conducted under Western Regional Project (WM-51). While this study is only concerned with the supply response of Montana producers, other states are currently conducting similar research in the major beet and cane producing areas.

and sugar manufacturing resources. The problem for this study is to determine the potential capacity of the Montana sugar beet and refining industry.

Objectives

The two major objectives of this research are as follows:

(1) To assess the economic potential sugar beet producing capacity of selected Montana irrigated regions under alternative prices of sugar beets and other competing crops.

(2) To assess the potential beet sugar manufacturing capacity based on the results obtained in objective one.

The organization of this dissertation includes a review of the literature of past sugar marketing research and economic models designed to estimate future supplies of a given commodity (Chapter II). The methodology of this study is explained in Chapter III. Supply response analysis is contained in Chapters IV - VIII for each sugar beet production area. Sugar refining capacity is analyzed in Chapter IX. The conclusions and policy implications resulting from the study are presented in Chapter X.

CHAPTER II

REVIEW OF RESEARCH COMPLETED AND IN PROGRESS

Sugar Industry Research

Some research has been completed on sugar (sucrose) substitutes. Hayenga studied the substitution potential of artifical and corn sweeteners for cane and beet sugar. 1/ He suggested that synthetic sweeteners will continue to substitute for beet and cane sugar provided that consumers continue to demand low calorie food products. However, the Food and Drug Administration will have to modify current regulations concerning the technical mix of synthetic sweetener with sucrose for foods if the artificial sweeteners are to be a significant substitute for sucrose.

Hayenga pointed out that little attention has been given to sweetener substitutes in sugar policy. The sugar program as it is now established is essentially designed to protect the American producer from foreign competition (at a relatively high cost to the domestic economy). Very little has been done to protect the sugar industry from an internal threat, artificial sweeteners. 2/

1/ Marvin Lee Hayenga, "Sweetener Substitution in the Food Processing Industry", Ph. D. dissertation, University of California, Berkeley, 1967.

2/ Marvin L. Hayenga, "Sweetner Compatition and Sugar Policy , Journal of Farm Economics, Vol. 49, No. 5, December 1967, p. 1365.

Ballinger also has studied sugar substitutes. He determined that non-caloric sweeteners, cyclamate, saccharin and mixtures of the two are currently being used much more than in the 1950's. The largest gains were reported in the beverage industry. Use of artificial sweeteners in 1970 is expected to be double that of 1965. An estimated 25 million pounds of artificial sweeteners or the equivalent of 915,000 tons of sucrose sugar will be consumed in 1970. This represents 3 percent of the United States 1970 sugar consumption. 3/

An analysis of the world sugar market shortly after Cuba aligned herself with the Communist Bloc countries was made by Bates. 4/ Cuban sugar was eliminated from United States imports as well as from other free-world sugar markets. Bates tried to determine the short run effects of Cuba's action on trade patterns. He found that price fluctuations were more a result of political action than of changes in transporting efficiencies. Furthermore, in the long run, under free competition less sugar would be produced in the United States and the U. S. S. R., and more would be produced in Central America, the Caribbean, and Cuba. Finally, Bates concluded that long run restrictions on Cuban sugar would force the United States to pay more for foreign sugar.

3/ Roy A. Ballinger, Noncaloric Sweeteners: Their Position in the Sweetener Industry, Economic Research Service, United States Department of Agriculture, Agricultural Economic Report No. 113, Washington, D. C., May 1967.

4/ Thomas Hobson Bates, "The World Sugar Economy and United States Supply Policy", University of California, Berkeley, 1966. Dissertation Abstracts, Vol. 27, No. 11, p. 3569-A. University Microfilm Incorporated, Ann Arbor, Michigan.

Goranson has examined the numbers of firms, sizes, location, and spatial arrangement of the beet sugar industry in the United States. 5/ He found that the number of beet sugar factories declined from 87 in 1939 to 59 in 1962. However, the average plant size increased from 1,600 tons of daily beet processing capacity to 2,600 tons over the same period of time. Also, the average distance between plants in the United States increased from 47 to 57 miles.

Four factors were thought to affect plant location. They were raw material location, transportation costs, economics of scale in manufacturing, and urban pull for inputs and finished products. Goranson concluded that processing plants should be located closer to supply areas to attain feasible economies in assembly and distribution of raw inputs and final product.

A considerable amount of work has been done by various experiment stations in determining the cost and returns to sugar beet production. 6/

5/ Leonard David Goranson, "An Analysis of the Location and Spatial Arrangement of the United States Beet Sugar Industry, 1939-1962", Ph.D. dissertation, University of Iowa, 1966. Dissertation Abstracts, Vol. 27, No. 9, Science and Engineering, p. 3137-B, University Microfilms, Ann Arbor, Michigan.

6/ See George W. Campbell, et. al., Sugar Beets: Estimated Costs and Returns, a Preliminary Report, College of Agriculture, Cooperative Extension Service, University of Arizona, 1965: K. D. Porter and B. J. McBain, Irrigated Specialty Crops of Alberta, Farm Cost Studies Division Dairy Branch, Alberta Department of Agriculture, 1954-1958. Walter W. Pawson and Aaron G. Nelson, Sugar Beets Economics of Machinery Investment, Arizona Agriculture Experiment Station, Report 238, August 1966: G. A. Fisher, Sugar Beets in Ontario, Farm Economics, Cooperatives and Statistics Branch, Ontario Department of Agriculture and Food, June 1966. Robert A. Yaggie and Laurel D. Loftsgard, Sugar Beet Production Costs and Practices in the Red River Valley, North Dakota State Agricultural Experiment Station Bulletin No. 466, Fargo, North Dakota, October 1966.

One study was completed by Stevens at the University of Wyoming. 7/ He found that the average Wyoming sugar beet farmer received yields of 14.8 tons of sugar beets per acre and that the average size of sugar beet contract was 125 acres. Stevens calculated that in 1964 the total average cost for growing an acre of sugar beets in Northern Wyoming was $190.72 or $12.47 per ton.

Montana Sugar Beet Research

The Montana experiment station has been interested in sugar beet production since 1898. 8/ As mentioned earlier, the first feasibility experiments to produce sugar beets in Montana are attributed to F. W. Traphagen. 9/ Beet growers in various parts of the state initially cooperated with Traphagen by sending beet samples to the University for chemical analysis.

The last general research on sugar beet production in Montana was a farm management study completed in 1956. 10/ Myrick and Huffman present

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7/ D. M. Stevens, et. al., Sugar Beet Production Costs and Practices for Wyoming, Mimeo Circular No. 206, Agricultural Experiment Station, University of Wyoming, Laramie, Whoming, January 1956. Also D. M. Stevens, Costs and Returns for Irrigated Crops in Wyoming, Agricultural Experiment Station Bulletin 467, University of Wyoming, Laramie, Wyoming, March 1967.

8/ See Appendix I for publications concerning Montana sugar production.

9/ F. W. Traphagen, The Sugar Beet in Montana, Montana Agricultural Experiment Station Bulletin No. 19, Montana College of Agriculture Bozeman, Montana, October 1898.

10/ D. C. Myrick and Roy E. Huffman, Sugar Beet Production in Montana, Montana State College, Agricultural Experiment Station Bulletin No. 525, November 1956, Bozeman, Montana.

a descriptive study of the Montana beet industry based on data gathered in 1947-48. The objectives of the study were to determine the physical environment for sugar beet production, evaluate the adoption of new methods and machines, and to determine the role of the sugar industry in the Montana economy.

The conclusions reached by these researchers indicated that sugar beets provided the most important cropping alternative in terms of income to irrigated farms. Myrick and Huffman also observed that a technological revolution was occurring in the Montana sugar beet industry. New tillage and harvesting methods were being developed, more advanced machinery was being adopted, and monogerm seed developments were improving the profitability of sugar beets in Montana.

Supply Responses, Methods, and Models

A supply function for a commodity is the realtionship between prices and the quantities of the commodity which producers are willing to place on the market for sale in a given time period, certeris paribus. The traditional supply function slopes upward to the right expressing a direct relationship between price and quantity. 11/

> "The nature of the supply function in any one period for a single agricultural product or the aggregate product of agriculture depends on (1) the nature of the physical produdtion in the relevant supply period, (2) the nature of the market for factors used in production . . . , (3) the structure of firm costs . . ., (4) the nature of household

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11/ Alfred Marshall, Principles of Economics, London, Macmillan and Company, Limited, 1930, pp. 455-476.

inter-relationships including the motivating forces behind the production response of farmers, and (5) the expectation of growers." 12/

There are a number of models and procedures that have been developed in order to estimate supply functions for a given commodity. Nerlove and Bachman suggest two general approaches for estimating supply functions. 13/ The first method involves the use of a production function and is commonly referred to as the synthetic approach. The second procedure, the historical approach, requires statistical times series data. Heady, however, suggested four methods of determining supply functions: (1) estimation through the use of a production function, (2) budget and budget-engineering analysis, (3) statistical time series analysis and (4) linear programming. 14/ However, they can be grouped into Nerlove and Bachman's classification.

A supply function can be generated from a production function by first estimating the production functions and then deriving the marginal and average physical product relationships. Cost curves are also derived from these relationships. Economic theory suggests that the marginal cost curve above the average variable cost is the firm supply curve in the short run.

12/ Earl O. Heady, Economics of Agricultural Production and Resource Use, New Jersey: Prentice-Hall, Incorporated, 1952, p. 677.

13/ Marc Nerlove and Kenneth L. Bachman, "The Analysis of Changes in Agricultural Supply: Problems and Approaches", Journal of Farm Economics, Vol. XLII, No. 3, August 1960, p. 541.

14/ Earl O. Heady, et. al., Agricultural Supply Functions, Iowa State University Press, 1961. (Refer to Contents and Introduction.)

Attempts have been made to derive a supply function from a production function. However, problems arise which are difficult to overcome in empirical research. These are (1) determining interfarm differences in managerial input use and technology, (2) separating multiple products which are interdependent on production, (3) and measuring of input levels, particularly capital. 15/ Studies by Griliches 16/ and Beringer 17/ have been designed to overcome some of these problems.

The farm budgeting method of deriving a supply function is attributed to John D. Black. 18/ The budgeting technique was developed in order to avoid some of the problems mentioned above that are inherent in the classical production function method of deriving a supply function. The budgeting method was used to discover typical farm organizations that may be expected to produce maximum farm income based on alternative prices for a given commodity.

The time required to determine a supply function via the budget process was great. High speed computers have not only reduced the time

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15/ Nerlove and Bachman, op. cit., p. 542.

16/ Zvi Griliches, "Specification Bias in Estimates of Production Functions", Journal of Farm Economics, Vol. 39, No. 1, February 1957, p. 8.

17/ Christoph Beringer, "Estimating Enterprise Production Functions from Input-Output Data on Multiple Enterprise Farms", Journal of Farm Economics, Vol. 38, No. 4, November 1956, pp. 923-930.

18/ John D. Black, "Research in Farm Management Scope and Method", Social Science Research Council, Bulletin No. 13, June 1932, pp. 87-101.

required to solve supply response problems through linear programming which includes budgeting, but they also have made it possible to handle case studies with more variables.

Budgeting-engineering techniques were also used to derive supply responses. This technique requires that supply functions be synthesized from input-output data gathered at the firm level. According to Johnson there are seven basic steps used in the synthesis process. 19/ The key step is the selection of appropriate input-output coefficients. Dean, et. al., have used this method to derive an aggregate normative supply relationship for cotton in the Imperial Valley, California. 20/

A supply curve can be developed through the use of statistical techniques. The process of fitting a line (regression analysis) to observed price-quantity data was carried out as early as 1917. 21/ Similar statistical supply response studies have been completed by Black for wheat and milk, 22/ as well as other studies by Bean. 23/

19/ Glen L. Johnson, "Budgeting and Engineering Analysis of Normative Supply Functions", Agricultural Supply Functions, Iowa State University Press, 1961, p. 171.

20/ See page

21/ H. L. Moore, "Forecasting the Yield and Price of Cotton". Reference cited in Black, Introduction to Economics for Agriculture, p. 247.

22/ John D. Black, "The Elasticity of Supply of Farm Products", Journal of Farm Economics, Vol. VI, No. 2, April 1924, p. 145.

23/ L. H. Bean, "The Farmer's Response to Price", Journal of Farm Economics, Vol. XI, No. 3, July 1929, pp. 368-387.

and Schultz. 24/ Cassels 25/ suggests the use of regression analysis rather than estimate of cost of production data to derive supply functions. 26/ He argues that production investigations are fundamentally sound but that they are of little value to businessmen and economists because production cost analysis per se offered little about the responsiveness of supply to price changes. 27/

There are limitations in using regression techniques in determining a supply function for a given commodity. One limitation is the inability of users of regression analysis to accurately reflect structural changes of a given industry in the model. 28/ According to Staniforth and Diesslin, even if researchers using regression techniques to estimate supply could adequately represent historical structural changes, greater

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24/ Henry Schultz, Statistical Laws of Demand and Supply, Chicago: University of Chicago Press, 1928, Chapter V.

25/ John M. Cassels, "The Nature of Statistical Suppy Curves", Journal of Farm Economics, Vol. XV, April 1933, pp. 378-387.

26/ Cost of production studies were made by the United States Tariff Commission for the purpose of setting tariff duties on specific commodities. Bulk line-cost curves represented as supply curves were determined from the cost of porduction data. Bulk line is a term used to indicate a line drawn at such a point that it will cover the major part of production and will presumably include all efficient producers. (Mark A. Smith, Tariff and Wool, New York: The Macmillan Company, 1926, p. 125.)

27/ Cassels, op. cit., p. 378.

28/ Elmer Learn and Willard Cochrane, "Regression Analysis", Agricultural Supply Functions, Iowa State University Press, 1961, p. 71.

problems arise in predicting future structural modifications if the technique is to serve as a tool for prediction. 29/

Another problem in using statistical techniques arises out of predicting future resource supplies. Brandow 30/ indicated that the results of his milk supply study were not to be used for the purpose of making reliable forecasts because there were too many unknowns in the model. Other problems are centered in trying to explain uncertainty and expectations, flexibility of fixed factors, and changes in technology over time. 31/ Also, defining the length of time required for producers to react and make adjustments to price changes has been difficult. One never is sure of the length of time (time lag) required by firm managers to respond to economic stimuli.

Despite these problems, regression technique has been a popular means of identifying supply relationships for agricultural products. One reason suggested by Nerlove and Bachman is that statistical techniques avoid aggregation problems that are inherent in synthetic typical or representative farm supply determination techniques. 32/ Furthermore, new

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29/ Sydney D. Staniforth and Howard G. Diesslin, "Summary and Conclusions", Agricultural Supply Functions, Iowa State University Press, 1961, p. 293.

30/ G. E. Brandow, Change in Milk Production in the United States 1924-1951, Pennsylvania Agricultural Experiment Station Progress Report 97, 1953.

31/ Nerlove and Bachman, op. cit., p. 545.

32/ Ibid, p. 545.

approaches to supply response, i. e., the synthetic linear programming analysis, really had not reached the refinement necessary to give researchers a reliable alternative as a means of estimating supply response until 1958. 33/

In summary, regression techniques were used to estimate supply response in historical studies. This approach is useful in specifying price-quantity relationships as they actually exist.

Linear programming, the synthetic approach to supply response estimation, has been used to determine supply relationships for agriculture commodities. 34/ This technique attempts to improve on regression techniques, but it is not without limitations.

Researchers using linear programming to derive a supply response for a given commodity have found difficulties in representing actual economic relationship with a mathematical format. 35/ By definition the relationship between variables in the model are linear whereas actual technical

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33/ Arvid C. Knudtson and Willard W. Cochrane, "A Supply Function for Flax at the Firm Level", Journal of Farm Economics, Vol. XL, February 1958, p. 117.

34/ Ronald Krenz, et. al., "Normative Supply Functions by Linear Programming Procedures", Agricultural Economic Research, Vol. XIV, No. 1, January 1962, p. 13. Gerald W. Dean, et. al., "Supply Functions for Cotton in Imperial Valley, California", Agricultural Economics Research, Vol. XV, No. 1, January 1963, p. 1.

35/ Dean E. McKee and Laurel D. Loftsgard, "Programming Intra-farm Normative Supply Functions", Agricultural Supply Functions, Iowa State University Press, 1961, p. 153.

relationships may be curvilinear. This has lead researchers to attempt to estimate the production function by linear segments rather than by a continuous linear function. 36/

A second limitation of linear programming models used to estimate supply response is the lack of knowledge about the factors which influence profit motives. Researchers have difficulties in including these subjective factors because of their qualitative rather than quantitative nature. Therefore, researchers believe that the supply response generated by linear programming is normative rather than positive. 37/ Normative functions describe what should happen as prices change whereas positive or predictive responses indicate what will happen as prices change, *ceteris paribus*.

Most linear programming models used to estimate supply are based on the response of a typical or representative farm. Two problems arise in using a representative farm as the basic unit of analysis. The first problem is centered in aggregating typical farm supply responses to form an area or regional response. Aggregation error is examined in greater detail in Chapter III. 38/ The second problem concerns partial equilibrium analysis. 39/

36/ Sydney D. Staniforth and Howard Diesslin, *op. cit.*, p. 297.

37/ See page for more on normative vs. positive supply responses.

38/ See page

39/ Dean, et. al., "Supply Functions for Cotton in Imperial Valley", *op. cit.*, pp. 7-14.

By inflating the typical farm supply response by the established regional restriction levels an area supply response is determined. Often times this procedure leads to over estimation of supply.

Partial equilibrium problems arise because it is assumed that farmers maximize profits based on the assumptions of the model (fixed resource levels and constant prices of competing enterprises). If growers were to make the adjustments often times suggested by model solutions, aggregate supply would probably reflect a much different price and quantity relationships; i. e., if sugar beet prices increase, resources should be shifted from competing crops to sugar beets. There would then be a reduction in the supply of competing crops, thereby raising their prices. However, in the linear programming models prices of competing crops are assumed to be constant. Linear programming solutions that do not reflect changing prices of competing crops tend to estimate a supply response greater than the response would be under actual conditions.

Regardless of the limitations of the linear programming model in estimating supply, the technique is superior to other approaches in estimating a long run price-quantity relationship. The method offers a better way of estimating structural changes and technology adoption than do other methods. 40/ Linear programming offers to researchers an improved tool for examining the effects of new variables introduced into

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40/ Staniforth and Diesslin, *op. cit.*, p. 297.

the problem situation. In addition, detailed examination of specific factors can be analyzed by sensitivity analysis. Further, linear programming provides a way to estimate supply response where historical data is insufficient. 41/

Variations of linear programming have been made for the purpose of improving the predictability potential. Day used recursive programming to estimate supply response. 42/ Recursive programming allows the researcher to systematically control the rate of adoption of technology over time. The optimum solutions determined in time period one are based in part on the solution derived in the previous time periods. Also, Gates and Kottke developed a two stage recursive programming model which considered technological change as a chance element to be determined outside the linear programming model. 43/ A Markov Chain process was used to predict farm numbers by milk-herd size. A recursive model was used to estimate farm output for each year under consideration. This two-stage model allows for decreases and increases in herd size simultaneously within the model whereas the traditional linear programming model is somewhat restricted to measuring changes in one direction.

41/ Heady, op. cit., p. 17.

42/ Richard H. Day, "An Approach to Production Response", Agricultural Economics Research, Vol. XIV, No. 4, October 1962. Also, Richard H. Day, Recursive Programming and Production Response, Amsterdam, The Netherlands: North-Holland Publishing Company, 1963, p. 37.

43/ John M. Gates and Marvin W. Kottke, The Dynamics of Milk Supply in Southeast New England, University of Connecticut Agricultural Experiment Station Bulletin 395, March 1966.

Dean, et. al., in investigating cotton supply attempted to avoid partial equilibrium problems. 44/ The researchers attempted to overcome their problems by considering winter lettuce and cotton simultaneously. First, they held the price of cotton constant and derived a supply function for winter lettuce. Next, an equilibrium lettuce price was established by forming the traditional intersection of lettuce supply and demand functions. At the equilibrium lettuce price, and with a fixed cotton price, optimum production of cotton was determined. This step was repeated with alternative cotton prices and equilibrium lettuce prices in order to form a supply function for cotton.

Sugar Beet Supply Response Studies

Robert Young completed an extensive study of the eastern beet sugar industry in 1963. 45/ The primary objective of the study was to analyze the economic factors that influence sugar beet production in Michigan and Ohio. Young projected the production of sugar beets, competing crops, and livestock enterprises to 1975. He used a linear programming model to generate optimum enterprise combinations and therefore production responses to changing prices and other economic factors.

44/ Dean, *op. cit.*, p. 1.

45/ Robert Alton Young, "An Economic Study of the Eastern Beet Sugar Industry", Ph. D. dissertation, Michigan State University, 1963. Also see Robert A. Young, *An Economic Study of the Eastern Beet Sugar Industry*, Research Bulletin 9, Michigan State University Agricultural Experiment Station, East Lansing, Michigan, 1965.

There were three general conclusions reached by Young. First, there would be favorable returns to sugar beet growers through 1968. Second, there would be economic conditions that would be favorable to continued but moderate sugar factory expansion. Finally, Young concluded that the construction of new plants would not be economically justified in the Eastern region in the next few years.

More specifically, the results of the study indicated that yields would increase and the cost of producing sugar beets would fall. These occurrences are attributable to the adoption of new technology. Among the important economic phenomena that Young found was that sugar beets yield the highest return per acre but with high costs for labor and machinery. However, the advantage of high returns per acre dissappear on certain soils. Also, the distance that a beet grower must haul his product for processing is an important factor in making the decision to produce sugar beets. According to Young, growers farming beyond 20 miles of a factory or beet dump find costs too high to continue production.

Pertaining to the model, Young indicated that there were a number of factors affecting sugar beet production that were very difficult to measure. He concluded, therefore, that the model has shortcomings as a tool for measuring total production relationships.

Spaulding completed a supply response analysis for sugar beets subject to alternative prices in two Utah counties in 1967. 46/ The objectives of the research were to determine the relative profitability of sugar beet production and to estimate a long-run supply curve for beets in response to changes in profitability of competing farm enterprises.

Secondary data were used by Spaulding to calculate costs and returns. Budgets were developed to supply gross and net returns per acre for each enterprise. Profitability ratios were calculated for each farm enterprise which indicated the relative returns to the factors of production (land, labor, and capital).

The Bureau of Reclamation and sugar company officials approved three productivity levels that were used on representative farms. Production levels encompassing three representative farm sizes of 40, 80, and 160 acres were examined. Representative farms included three crop and livestock combinations (all crop, crop-dairy, and crop-beef).

Spaulding calculated the supply response for each representative farm with the use of linear programming. Parametric programming was used by the researchers to calculate the desired variations in sugar beet prices. Variable price programming enabled the researcher to calculate

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46/ Brent W. Spaulding, "Estimated Long-Run Supply Response to Changing Profitableness of Sugar Beet Production in Box Elder and Cache Counties, Utah, from 1966-1975", Unpublished Masters Thesis, Utah State University, Logan, Utah, 1967.

solutions at extremely high price levels. Reduced sugar beet price levels were introduced and optimum enterprise combinations were therefore changed. Price levels were decreased until sugar beets were eliminated from the solution. As price levels fell alternative enterprises substituted for beets and a supply relationship was established.

Finally, Spaulding combined the representative farm supply responses (micro-supply) into the various county responses. All available land and water were assumed to be used by the representative farms designated. An average of the six estimates were used to define the county supply response curves. Individual supply functions were summed horizontally to determine the function. An aggregate supply curve was established by combining the two county responses.

Comparison of Methods to Estimate Supply Responses

In summary, there are two basic approaches to supply response studies; (1) the synthetic method which over the last few years has been dominated by linear programming studies and (2) regression analysis based on time series data. Both methods have advantages and limitations.

Schaller and Dean compared a recursive programming model to a statistical model based on time series data. 47/ Both techniques were used to project changes in the production of cotton and other selected crops at

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47/ W. Neill Schaller and Gerald W. Dean, Predicting Regional Crop Production, An Application of Recursive Programming, Technical Bulletin 1329, United States Department of Agriculture, Washington, D. C., April 1965.

Fresno, California. Results indicated that the recursive programming model was less accurate than the regression technique. The recursive analysis led the researchers to conclude that large acreage changes would occur from year to year. However, actual changes were relatively small. The regression technique appeared to be a more appropriate predicting tool in this case. However, one advantage in using recursive programming was that structural changes in acreage over time were determined. Regression analysis results did not show these structural changes.

Zepp pointed out that the synthetic-type models often overestimate actual production. 48/ It may be possible that regression techniques used along with synthetic procedures may result in a model that takes into consideration historical trends as well as anticipated technological and institutional changes thereby reducing overestimation of production. Regression procedures avoid aggregation problems that plague researchers using linear programming with representative farm techniques. Zepp concluded that the regression type model is a more useful aid in making short term projections of aggregate milk output than the synthetic models. Furthermore, the regression model based on trend data gave closer estimates of actual milk supplies (1960-1965) than recursive programming

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48/ Glenn A. Zepp, "An Evaluation of Selected Aggregate Milk Output Response Models". Unpublished Ph. D. dissertation, Pennsylvania State University, September 1967.

for the same time period. The author suggested that linear programming models are better adapted for studying long-run projections that involve technological and institutional change.

CHAPTER III

ANALYTICAL MODEL AND RESEARCH METHODOLOGY

The purpose of this chapter is to develop the analytical model and methodology used to assess Montana's potential sugar beet producing capacity under alternative price situations. The linear programming model and assumptions are explained. Variable price programming and problems associated with normative discontinuous supply functions are examined. The concluding portion of the chapter is devoted to the research methodology used in this study.

Analytical Model

The linear programming model is applicable to problem situations that offer a number of alternative profit-making enterprises called activity levels. The optimum combination of activity levels is dependent upon the mix of scarce productive resources referred to as restrictions.

The basic elements of a programming model include an objective function, input requirements, and a set of restriction equations.

The objective function is denoted as

(1) $Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$ where the x's represent the unit of production (tons, bushels, gallons) and c_j's are the net profit per unit of x in the case of maximization problems or the cost per unit of x in the dual solution. Input requirements are specified such that

(2) $a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n$

where each x_i value is the unit of production and is greater than or equal to zero and each a_{ij} variable represents the quantity of the resource unit needed to produce a unit of the j-th product. Each set of input levels is subject to the supply of a given resource that is available for the production process.

A linear inequality exists such that

(3) $a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n \leq b_i$

where b_i represents the supply of a given resource. The objective function, equation one, is maximized or minimized subject to the set of linear equations, inequality (3).

The process is to select those activity levels (x_i) that maximize profits (Z) subject to the resource requirement (a_{i1}) to produce product x based on the amount of resource (b_i) available for the production process. According to Heady this process is based on the following five assumptions: (1) additivity, (2) linearity, (3) divisibility, (4) finiteness, and (5) single value expectations. 1/ However, profit maximization is a primary assumption.

The assumption of additivity and linearity means that the total product produced is equal to the sum of the individual products. Also, the total amount of resources used in the production process must be equal to the sum of the resources used by the individual activity levels.

1/ Earl O. Heady and Wilfred Candler, Linear Programming Methods, Ames, Iowa: The Iowa State College Press, 1958, pp. 17-18.

Interaction between resources in the production of a commodity is assumed to be non-existent. Those enterprises that interact with one another must be included in the model as one activity.

Activity levels are often represented in the solution in fractional form, i.e., 20.67 acres of beans, 158.32 cows. The assumption of divisibility allows resources to be used as continuous variables infinitely divisible. Rounding solution values to the nearest whole number is required to meet actual situations.

Finiteness has reference to the scope of the model. Each linear programming model has certain bounds which tend to limit the solution just as actual situations are limited by availability of resources and the number of competitive alternatives. The assumption, therefore, is practical insofar as it reflects the actual situation faced by many farmers, that of limited alternatives and resource levels.

Each alternative activity level, price coefficient, and resource restriction, as well as input-output coefficient, is assumed to be known with certainty. The assumption of single value expectation results in the use of estimates that carry no attached uncertainty.

According to Candler and Heady, the assumptions of linear programming must be met if solutions are to be precise. 2/ However, any model only approximates actual production processes and linear programming assumptions.

2/ Ibid., p. 268.

Variable Price Programming

Variable price programming was the basic analytical tool used in this study. The procedural requirements for variable price programming are: (1) the problem must first conform with linear programming methods, (2) an optimum solution for a given price situation must be derived, and (3) the determination of the price change necessary for another plan to become optimum must be determined. 3/

The supply response for a selected commodity is determined by constructing a linear program with an objective function consisting of alternative activities, restrictions, and appropriate input-output coefficients. For the commodity under examination, a selling activity is added to the objective function and assigned a price. A supply response for a commodity is generated by first determining an optimum solution for the program at the assigned price. The solution designates so many acres of a commodity based on the competitive nature of alternative activity levels. Computer output reports show the upper and lower values between which the price of a commodity can vary without changing the optimum solution. 4/ By introducing another price for the commodity exogeneously a new optimum solution is derived. All prices and input

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3/ Ibid., p. 265.

4/ IBM Application Program, 1620-1311 Linear Programming System (1620-CO-04X) Program Reference Manual, p. 59.

levels of other commodities are held constant while the procedure is repeated for the commodity in question within practical price limits. The results showing various quantities of the commodity grown at alternative prices are plotted as a supply response.

Stepped Supply Response

The supply response derived by revising a linear programming objective function is represented as a series of linear segments. This means that a given optimal solution will be stable over a range of prices. The function is not smooth or continuous like the traditional classical supply curve. Steps in the function are established at points indicating a change in the optimum solution plans with respect to changes in the price of the commodity in question, ceteris paribus.

The interpretation of the stepped supply response derived through linear programming should not be confused with the traditional continuous supply curve obtained by using a production function. According to Cochrane,

> "The term supply and response are often used interchangeably. . . however, the term supply is used to describe a specific type of relation [whereas] the term response is used to describe a more general, or what Heady called a mongrel relation." 5/

5/ Willard W. Cochrane, "Conceptualizing the Supply Relations in Agriculture", Journal of Farm Economics, Vol. 37, No. 5, December 1955, p. 1162.

Further, supply refers to,

> ". . .how a quantity of a product offered for sale varies, as its price varies, relative to other product prices, for some given time and technology. Response on the other hand, refers to how the quantity of a commodity offered for sale varies with the changes in the price of the commodity. . . ."

regardless of the other factors that may enter into the situation. 6/ "The response relation describes what will happen to the quantity of a commodity offered for sale when we do not hold all other things constant." 7/

There is more to the problem of traditional supply curves and linear programming response interpretation than semantics. A continuous production relationship is the only means whereby marginal productivity and, therefore, the marginal physical product relationships can be represented. It follows that the marginal cost curve of the firm which represents the supply curve in the short run is also continuous.

Kottke questioned whether or not a stepped supply response had the same conceptual basis as a smooth supply function. 8/ He took the position that ". . . the interpretation of a step supply function follows the conventional explanation of a smooth supply function, except that the steps modify and accentuate parts of the interpretation." 9/

6/ Ibid., pp. 1162-1163.

7/ Ibid., pp. 1162-1163.

8/ Marvin Kottke, "The Anatomy of a Step Supply Function", Journal of Farm Economics, Vol. 49, No. 1, Part 1, February 1967, p. 107.

9/ Ibid., p. 107.

Kottke proceeded to show how the anatomy of the step supply response included (1) marginal cost concept represented by the horizontal sections and (2) the profit maximizing supply response represented by the vertical sections.

If, in fact, the response derived through the linear program is a supply curve or supply function, then a marginal cost curve is known. It follows that a marginal physical product function exists. Furthermore, if a marginal product curve exists then a production function must exist. Therefore, there is no need to use linear programming to derive a supply response because the production function and the price of the inputs are all that is necessary to derive the supply curve.

For the purposes of this study, supply response or supply estimate are interchanged with the terms supply curve and supply function. The terms will refer to the variable price programming technique of determining supply and under no circumstances are the terms to be interpreted as meaning the same as supply curve or function in the classical sense.

Normative and Predictive Supply Responses

The supply responses generated through the use of various schemes (production function, budget, engineering, statistical and linear programming) are either normative or positive. There is some disagreement among researchers as to the nature of the derived supply response.

Heady argues that linear programming supply response are normative. 10/ That is, they explain what farmers ought to do under stated conditions. A normative supply function describes the quantities which should be produced in order to maximize profits at various prices. 11/ Researchers face difficulties in empirically defining actual situations; therefore, the supply responses derived are considered normative. For example, it is assumed that farmers maximize profits in the linear programming model. However, farmers may really maximize utility or sales or perhaps minimize risk. If these factors are ignored the results will be of limited value in predicting the future. Researchers can only say that certain production patterns will occur if defined norms, i.e., profit maximization, are followed or achieved over the time period under consideration.

Johnson indicated that the term normative is used by some to explain supply estimates that are inaccurate, while accurate estimates are labeled predictive or positive. 12/ He suggests that appropriate handling of subjective factors will lead to more accurate (predictive) supply response

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10/ Heady and Candler, Linear Programming Methods, op. cit., p. 265. Also refer to Dean, "Supply Functions for Cotton in Imperial Valley, California", op. cit., p. 2, and Ronald D. Krenz, et. al., "Normative Supply Functions by Linear Programming Procedures", Agricultural Economics Research, op. cit., p. 14.

11/ Heady and Candler, op. cit., p. 265.

12/ Glenn L. Johnson, "Budgeting and Engineering Analysis of Normative Supply Functions", Agricultural Supply Functions, Iowa State University Press, 1961, p. 170.

than would similar attempts that disregard such considerations. 13/ That is, programming or statistical analysis empirically designed to measure the beliefs, norms, and values of farmers will improve the capability of the model to predict even though the explanatory variables are by nature normative.

Day suggests ten categories that must be considered if analysis is to be meaningful for prediction: technological change, uncertainty, demand-supply interactions, adjustments over time, policy, yield acreage changes, supply of inputs, specialization and competition, investment, and output interdependence. 14/ Econometricians and linear programmers have made efforts to incorporate these important factors in models so that results can be used to predict future events. However, it appears that much work remains to be done to further perfect linear programming supply response models.

Representative Farm Models

Most supply response studies using variable price programming to derive a supply response use a "typical" or "representative" farm as the basic unit. 15/ Typical characteristics are defined for the

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13/ Ibid., p. 170.

14/ Richard H. Day, "Recursive Programming and Supply Prediction", Agricultural Supply Functions, Ames: Iowa State University Press, 1961, p. 108.

15/ See Knudtson and Cochrane, "A Supply Function for Flax at the Firm Level", op. cit., Krenz, et. al., "Normative Supply Functions by Linear Programming Procedures", op. cit., Dean, et. al., "Supply Functions for Cotton in Imperial Valley, California", op. cit.

representative farm, i.e., alternative enterprises, pertinent restriction levels, and appropriate input-output coefficients. A supply response for a given commodity is derived for the typical farm. The resulting response is expanded by the number of farms in a defined region resulting in a regional supply response.

There are problems, however, in using representative farm linear programming models to derive supply responses. These problems are aggregation error, specification error, and sampling error. 16/

Aggregation error is the difference between the summation of the representative farm supply responses and the area supply responses. 17/ Aggregation error is due in part to methods that do not reflect accurately the way farm managers respond to economic stimuli. 18/ Typical farm managers may not respond to price change because of unique problems that were unidentified by researchers in choosing them as representative. Futhermore, the actual selection of typical farms from stratified regions leads to aggregation error. Stratifying many farms into a homogeneous group may lead to overestimating supply because too many variables are overlooked in the stratification. 19/

16/ See p.

17/ George E. Frick and Richard A. Andrews, "Aggregation Bias and Four Methods of Summing Farm Supply Functions", *Journal of Farm Economics*, Vol. 47, August 1965, p. 696.

18/ Randolph Barker and Bernard F. Stanton, "Estimation and Aggregation of Firm Supply Functions", *Journal of Farm Economics*, Vol. 47, No. 3, August 1965, p. 706.

19/ *Ibid.*, p. 706.

Stovall argues that other errors are committed before aggregation errors occur. 20/ Specification and sampling errors may lead to aggregation bias. Specification error is due to the failure of the model to reflect accurately the conditions actually facing the farm firm. 21/ Sampling error occurs when the population parameters are estimated through statistical sampling techniques. 22/ Sampling errors may have a direct influence on aggregation errors. If sampling errors were zero, specification and aggregation errors could exist. That is, there will always be difficulty in including in the model all the important variables that influence supply.

The model developed in this study to estimate a long run supply response for Montana sugar beet production has been designed to minimize aggregation error. The model does not use representative or typical farms as the responding unit. Rather, a set of regional models have been developed reflecting the areas in the state supporting sugar beet production.

Montana Sugar Beet Supply Response Model

The model used in this study for the purpose of estimating a long run supply response for sugar beets is not based on typical or

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20/ John G. Stovall, "Sources of Error in Aggregate Supply Estimates", Journal of Farm Economics, Vol. 48, No. 2, May 1966, p. 477.

21/ Ibid., p. 478.

22/ Ibid.

representative farms. An attempt to assess the potential, not actual, sugar beet production in 1980 has led to the development of a model that requires farming regions as the basic unit. This model appears to simplify the estimation technique because aggregate resource levels are obtained easily and farm numbers and sizes do not have to be projected.

Five regional farms have been defined. A regional farm consists of many smaller farms. However, the regional farm is not dependent upon a predetermined representative farm within the region.

A supply response for the region will be determined dependent upon (1) the resources in the region, (2) the farming practices within the region, and (3) the prices received and prices paid by farmers within the region. The regional supply responses will be aggregated resulting in a long run supply estimate for sugar beets in Montana.

Area Under Study:

Sugar beet production in Montana is limited to irrigated regions having 95 or more days of growing season. The irrigated portions of the state that traditionally have supported sugar beet production can be divided into five areas which correspond to three sugar factory districts.

The Great Western Sugar Company contracts for sugar beets in the mid-Yellowstone Valley, Milk River Valley, the Bitteroot Valley, and the Crow Creek Irrigation Project. The latter two areas are considered separately as regional farms. The mid-Yellowstone Valley and the Milk River Valley constitute another regional farm. Each of these areas are widely separated and have unique characteristics. The Holly Sugar

Company has two factory districts in Montana. They are the extreme lower Yellowstone Valley and the Big Horn River Basin represented as the Sidney and Hardin farms, respectively (Figure 2).

There are other irrigated areas in the state that could support a sugar beet crop. However, it is beyond the scope of this project to include these areas in the supply response model. Determination of potential 1980 Montana sugar supplies will be restricted to those areas that produced sugar beets during the 1966 campaign.

Sampling Frame:

The population considered in this study is the farmers that supply sugar beets to refining factories located in Montana. This universe includes sugar beet growers in Montana, Wyoming, and North Dakota.

The major purpose in sampling the population was to determine the cost of growing sugar beets and other irrigated crops. The information gathered and tabulated was used as the primary coefficients in the objective function and restraint equations of the linear programming model.

The sample frame was limited to farmers that grow sugar beets in Montana. However, the farmers in northwest North Dakota were included in the survey. Wyoming sugar beet growers as well as farmers living in the Bitteroot Valley of Ravalli County, Montana, were not included

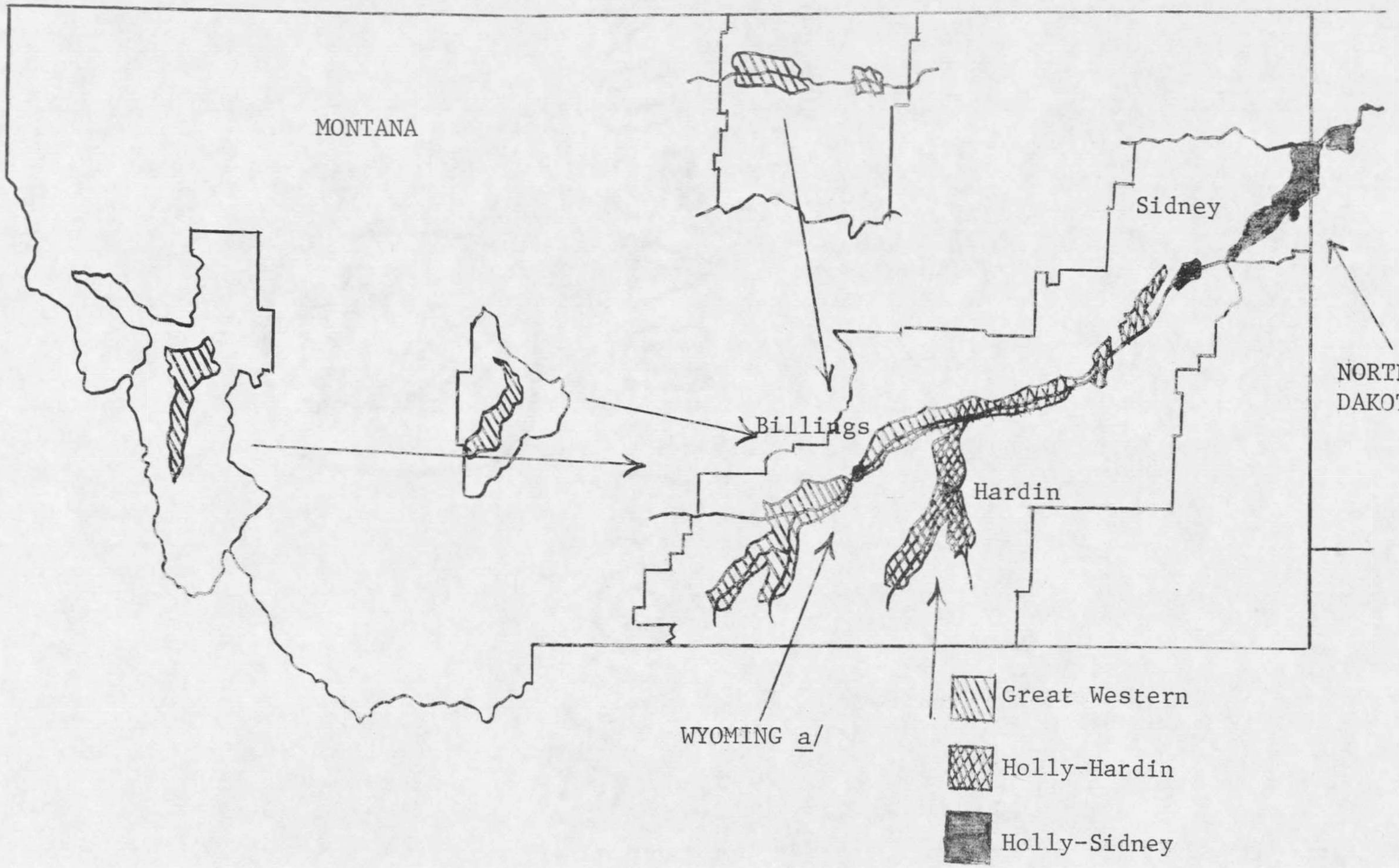

Figure 2. Montana Sugar Factory Districts, 1966.

a/ Arrows indicate sugar beet flow patterns.

because they were recently interviewed in a cost study carried out by the University of Wyoming and the Economic Research Service. 23/

During the summer of 1967, sugar beet growers in four irrigated areas in Montana and North Dakota were surveyed. The sample frame was established from lists of sugar beet growers furnished by Holly and the Great Western Sugar Company. Each grower was represented in the population by their sugar beet contract number. This number was the key to the selection of the sample.

A table of random numbers was used to select the sample. Ten percent of the total number of growers were selected in each factory district at random and with replacement. Many growers had more than one contract number. If any one grower was selected more than once, his number was replaced and another number drawn. Twenty alternate growers were selected in each factory district to replace those growers that would not or could not cooperate. All 4-H sugar beet contracts were eliminated from the sample because of the small acreage involved.

A pilot study was conducted with selected sugar beet growers to pre-test the questionnaire. Later, a letter was sent to each sugar beet grower drawn in the sample introducing the project and inviting participation in the study. The letters were sent two to ten days

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23/ Dale M. Stevens, Cost of Producing Sugar Beets and Irrigated Crops in Wyoming, op. cit., and J. Wayne McArthur, "Economic Impact of Some Alternative Uses for Resources Historically Devoted to Sugar Beet Production and Refining, Ravalli County, Montana, 1965", Review draft, NRED, ERS, USDA, pp. 10-66.

ahead of the enumerators, after which one of four enumerators contacted the grower for an appointment. The number of sugar beet growers in the three regional farms sampled was 1,124. There were 122 or 10.9 percent of these growers interviewed (Table IV).

TABLE IV. SAMPLING SUCCESS IN THREE REGIONAL FARMS, 1966.

Regional Farm	No. of Growers in Population	No. of Growers Interviewed	Sampling Percent
Hardin Regional Farm	203	30	14.8
Sidney Regional Farm	392	57	14.5
Billings Regional Farm	529	35	6.6
Totals	1,124	122	10.9

The questionnaire used in the survey was designed specifically to determine the amount of inputs required to produce irrigated crops on regional farms. 24/ Each farm participating in the study was completely inventoried with respect to cropping programs, livestock, machinery, improvements, and land use. An aggregate income and cost schedule was made. Rental agreements, rotations, and family labor use was ascertained. Important information concerning the use of water was gathered along with specific data pertinent to the use of seasonal labor.

24/ See Appendix II for the questionnaire used in interviewing the sugar beet producers.

Each irrigated crop was examined carefully to determine the number and type of labor, machine, tractor, and truck hours and/or miles necessary for pre-harvest and harvest work. The use and cost of fertilizers, herbicides, and insecticides were determined for each crop. Seeding rates and costs were calculated. The nature of livestock enterprise organization was also determined.

Assumptions:

The following assumptions were made in order to clarify the model. The standard assumptions of linear programming are assumed to be valid. 25/ Of course, the assumptions for each regional farm model vary. Therefore, an explanation of the primary assumptions will accompany the regional farm descriptions in Chapters IV - VIII. The following general assumptions are made for all the defined regional farms.

(1) Sugar beet growers are assumed to maximize profits.

(2) United States Department of Agriculture sugar beet acreage allotments and controls will not affect the number of acres harvested in 1980.

(3) All farmers in the irrigated regions of Montana are assumed to have equal opportunity and desire to grow sugar beets.

(4) Unlimited Montana processing capacity is assumed for 1980. 26/

25/ See p. 38.

26/ This is a temporary assumption. Chapter IX has been designed to assess the sugar refining capacity in Montana.

(5) Water is a critical resource for the production of sugar beets in Montana. Farm district climates are such that sugar beets must have water to produce profitable yields. The physical quantity of water that is currently available in established irrigation districts appears to be more than is needed even in low water years. The quality and quantity of irrigation water is assumed to be in unlimited supply both physically and institutionally in 1980. However, the price of water is reflected in the net revenues coefficients of the objective function.

(6) Capital is assumed to be in unlimited supply.

Under these assumptions the various parts of the linear programming model are developed below including (1) activities, (2) restrictions, and (3) input-output coefficients.

Activities

A number of cropping practices and livestock operations represent enterprise alternatives for farmers on irrigated farms in Montana. Among the cropping alternatives facing the farmer are sugar beets, alfalfa hay, corn silage, wheat, oats, beans, and barley. Less popular alternatives to sugar beet production includes potatoes, corn for grain, malting barley, sudan grass, sorghum, grass hay, sain-foin, and improved pasture. Alternative livestock operations include beef and lamb feeding, dairy, hog feeding, poultry, and beef cows. Steer-grazing on wheat stubble and ewe-lamb operations are also economic alternatives.

In order to minimize specification error in the model, a number of cropping patterns were selected representing those crop rotation preferences that farmers have used over the last 20 years in the various regions. Cropping patterns studied at the agricultural experiment stations within each regional farm were also incorporated into the objective function of each model.

Crop rotations are important to Montana sugar beet growers because the proper combination of nematode host and non-host crops is necessary for continued high sugar beet yields. Nematodes are a problem to sugar beet growers in some areas of Montana. 27/ Sugar beet growers use crop rotations to break the life cycle of the nematode. Crop rotations also serve to maintain the soil quality by restoring essential growth elements that have been depleated. Research carried out at the Huntley, Montana, Agriculture Experiment Station has shown that sugar beet seedlings are susceptible to parasitic organisms in the soil when rotational patterns are not used to replace essential elements. 28/ The specific rotational patterns used by farmers in the regional farms are examined more closely in Chapters IV - VII.

27/ Morgan A. Goldin and Edsel C. Jorgenson, The Sugar Beet Nematode and Its Control, U.S.D.A. Leaflet No. 486, January 1961.

28/ W. E. Larson, et. al., Irrigated Crop Rotations at the Huntley Branch Station, Montana Agricultural Experiment Station Bulletin No. 535, Montana State College, Bozeman, Montana January 1958. M. N. Afanasiev, and H. E. Morris, Diseases of Sugar Beets in Crop Rotations at the Huntley Branch Station, Huntley, Montana, from 1936 to 1941, Montana State College, Agricultural Experiment Station, Bulletin 419, Montana State College, Bozeman, Montana, November 1943, p. 1.

The profitability of each cropping pattern included in the regional farm supply response models was determined by using cost data gathered from Montana sugar beet growers. The variable cost per acre was determined for each crop within the rotation. The sum of the costs of production for each crop in the rotation represented the total variable cost to grow one unit of the crop sequence. The total cost of growing one unit of the rotation subtracted from the total revenue of one unit of rotation resulted in the net revenue or c_j coefficient for one unit of a given cropping sequence.

The objective function of each regional farm reflected the net revenue per unit in producing selected crop rotations. In order to determine a 1980 supply response for sugar beets each activity level net revenue coefficient was projected to 1980. This was done by projecting the costs of inputs, crop yields, and prices received in 1980.

Input costs were projected to 1980 from the average percentage increase or decrease in prices paid by farmers for selected inputs between 1947 and 1966. For example, a small tractor, PTO auto-tie baler, three-bottom plow, one section of harrow, one-half ton pickup truck and a four-tine pitch fork were the implements selected for the purpose of measuring the average percentage change in the prices paid for machinery. A simple linear estimation of the 1980 price was made for each implement. The percentage change in prices paid for a given input was calculated by comparing 1966 and the projected 1980 prices. The percentage change in price from 1966 to 1980 between each year for each implement were averaged. i.e., from 1966 to 1980, one might expect a 48 percent increase in the price of machinery. This represents 2.69 percent change in the prices paid per year for machinery. Other inputs were examined in a similar manner. The 1966 cost of producing those crops that were included in the selected regional rotations were expanded by the average percentage change in the costs of inputs expected from 1966 to 1980 for all inputs.

Crop yields were determined for 1980 from guide lines set by the Great Plains Agricultural Council (GPC), the Economics Research Service (ERS), and the Soil Conservation Service (SCS). 29/ Where this source was deficient a linear projection was made using crop yield data for Montana over a 20-year period.

Prices received by farmers for crops produced on irrigated farms in Montana were projected to 1980 as follows:

$$\frac{\text{1962-65 Montana Price}}{\text{1962-65 U. S. Price}} \times \text{1980 U. S. Price} = \text{1980 Montana Price}$$

Where data was not available to complete the above calculation, a simple linear projection was made based on the prices received by Montana farmers over a 20-year period.

In summary, the objective function of each regional farm supply response model reflects the alternative cropping activities expected in

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29/ Great Plains Agriculture Council State Technical Committee, "Current Normal Acreage and Current Normal and Projected Yields and Fertilizer Use", Economic Research Service and Soil Conservation Service, United States Department of Agriculture, University of Nebraska Computing Center, 1966.

1980 in Montana regional farms. The net revenue coefficients of the regional farm objective functions reflect the 1980 cost of inputs, crop yields, and prices received.

Restrictions

There are a number of factors that limit the production of sugar beets in Montana. Individual factors of production such as land, labor, capital, water, and machinery are limeted in supply to the individual farm and, therefore, represent restriction levels for sugar beet production. Other limitations that may restrict sugar beet production in Montana are U. S. D. A. sugar beet quotas, factory contracts, distance from refining facilities, grower knowledge, experience, attitude, and age.

Each of the regional farms selected for this study include capital, water, labor, and land as the restrictions to sugar beet production. Capital and water are included in the various regional models as costs of production only. These costs reflect the prices paid for capital and water in selected districts within the regional farm.

Other factors that may influence sugar beet production such as governmental quotas are assumed not to be in affect to 1980. Factory contracts are assumed to be in unlimited supply in 1980. Subjective criterion that affect sugar production such as grower attitudes, age, and knowledge are not included in this study because these factors are difficult to quantify.

Since land represents the major limiting factor of sugar beet production in Montana during 1980, a number of land types and classes capable of supporting sugar beets are included in the model. The Soil Conservation Service (SCS) provided eight soil classifications capable of supporting sugar beets. These classifications are based on land slope, texture, permeability, drainage, and organic matter. 30/ Because it was difficult to assign specific yields to a given soil type, the Soil Conservation Service provided the help necessary in breaking down their eight soil classifications into the four classifications used by the Bureau of Reclamation. Crop yield data was available for the four Bureau of Reclamation classes of soils in selected areas of Montana.

The 1966 inventory of irrigated land was determined for each district within each regional farm. The 1980 inventory of sugar beet producing lands were ascertained by adding to the 1966 inventory new irrigation projects to be completed by the Bureau of Reclamation, State Engineers Offices, and private individuals. A projected 1980 irrigated land inventory capable of supporting sugar beets was established for each district within each regional farm.

Labor, the other major factor limiting the production of sugar beets, consists of migrant hand labor, local part time labor, and family labor. There still exists considerable migrant hand labor used to produce Montana sugar beets. For the most part, farmers contracting with Great Western Sugar Company thin their sugar beets mechanically. However,

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30/ A. A. Klingebiel and P. H. Montgomery, Land-Capability Classification, U.S.D.A., Soil Conservation Service, Agriculture Handbook No. 210, Washington, D. C., September 1961.

Holly Sugar Company growers primarily use hand labor for hoeing weeds and thinning beets. The supply of domestic migrant labor is provided through the sugar factory representatives. Growers have very little, if any, trouble securing labor at the right time to care for the thinning process. Labor indigenous to the regional farms is used mostly in non-beet crops such as hay, grains, and corn silage. The survey showed that Montana sugar beet growers and their families care for the sugar beet crop. According to reports from the growers, preharvest work, including irrigation, is carried out by family labor. There are, of course, exceptions such as some harvest operations that require one or two additional men.

The amount of family labor available on irrigated farms within the regional farms has been projected to 1980. The number of irrigated farms within each regional farm was determined for 1980 through simple linear regression. The number of irrigated farms in 1980 multiplied by the number of family laborers per farm, the hours per day, and the crop working days per year (Table V), resulted in the number of hours of family labor available for 1980.

Number of Farms (1980)	X	Number of Family Laborers Per Farm (Average)	X	Ten-Hour Working Day	X	177 Working Days	=	The number of hours of family labor available in a given year.

Grower interviews showed that 1,375 units of family labor per farm was available for 177 days.

TABLE V. EXPECTED WORKING DAYS BY MONTH IN IRRIGATED CROP PRODUCTION, MONTANA SUGAR BEET PRODUCING AREAS, 1980.

Month	Estimated Working Days in Month a/	Number of Working Days Expected b/
April	15	13
May	31	20
June	30	24
July	31	27
August	31	27
September	30	26
October	31	27
November	15	13
Totals	225	177

a/ April and November are sugject to adverse winter weather.

b/ Not including Sundays.

An attempt was also made to estimate farm labor other than family labor in regional farms for 1980. However, because most of the hired seasonal non-migrant indigeous labor was high school age workers, no restriction level was established. It is, therefore, assumed that sufficient lacal labor would be available. The investigations determined that labor exogenous to a given region was primarily migrant hand labor. Few sugar beet growers indicated that endogenous labor hoed and thinned beets.

Montana Supply Response Procedure:

Each defined regional farm was programmed separately to estimate the long run supply response for sugar beets. Each model was designed to estimate the supply response for sugar beets by irrigation district within the regional farm. The optimum solutions included the most profitable rotation plans based on the land and family labor available.

A given regional farm model was programmed beginning with a sugar beet price of $14.00 per ton. The objective function activities, including sugar beets in the rotation pattern, were revised and new optimum solutions generated.

A sub-routine was developed to calculate the changing net revenue coefficients for those activity levels with sugar beets in the cropping sequence. Sugar beet prices were varied at 50 cent intervals, $14.00 to $21.50 per ton, while all other prices were held constant. An optimum solution was determined for each objective function revision.

Computer output was in a form such that optimum solutions were represented by the number of units of a given rotation, i.e., 150 units of rotation in District 1 on Land 2. This value was interpreted the following way. If the number of units of land in one unit of Rotation 1 was six, then 150 X 6(900) would equal the number of acres of land in that rotation in the optimum solution. If 1/3 of the land in the rotation were sugar beets, then 1/3 of 900, or 300, acres represented the number of acres of sugar beets grown in Rotation 1 in a given district on a Land 2 at an assigned price.

The interpretation of each optimum solution for each irrigation district over a range of sugar beet prices was made. The resulting coefficients were plotted to form a long run discontinuous supply response for a sugar-beet district. The district responses were summed horizontally to form a regional-farm long-run discontinuous supply response for sugar beets. The summation of the five regional farm responses resulted in a long run normative supply response for sugar beets in Montana.

The regional long run supply responses for sugar beets were compared with similar responses derived using representative farms. Three typical farms, based on size, were chosen to represent each region. A supply response was made for each size farm selected. The response for each typical farm was expanded by the number of farms of that size expected in 1980. The three typical farm expansions were then summed to form another regional long run supply response for sugar beets.

CHAPTER IV

SUGAR BEET PRODUCTION RESPONSE--EAST CENTRAL REGION

Five regional farms in irrigated valleys of Montana have been defined for the purposes of estimating a long run supply response for sugar beets. This chapter has been designed to describe the easternmost sugar beet production area in Montana. The supply response results for the region are presented including a comparison of the regional and representative farm sugar beet supply estimates.

Area Under Study

The irrigated areas of Richland, Dawson, and Prairie Counties of the east central part of Montana and a small portion of Williams County, North Dakota represent Regional Farm I (Figure 3).

Regional Farm I is further divided into three districts based on irrigation projects. District 1 is represented by the Bureau of Reclamation's Lower Yellowstone Irrigation Project. The district extends from Intake, Montana, in Richland County northward on the west side of the Yellowstone River to the abandoned town of Nohly, Montana, on the Missouri River.

The Buffalo Rapids Irrigation Project, managed by the Bureau of Reclamation is District 2. The lands bordering the Yellowstone River in Prairie County from Terry to an area north of Fallon are the district boundaries. The third district of Regional Farm I, is Williams County, North Dakota. The Buford-Trenton Irrigation Project, located on the north side of the Missouri River downstream from the Missouri-Yellowstone River

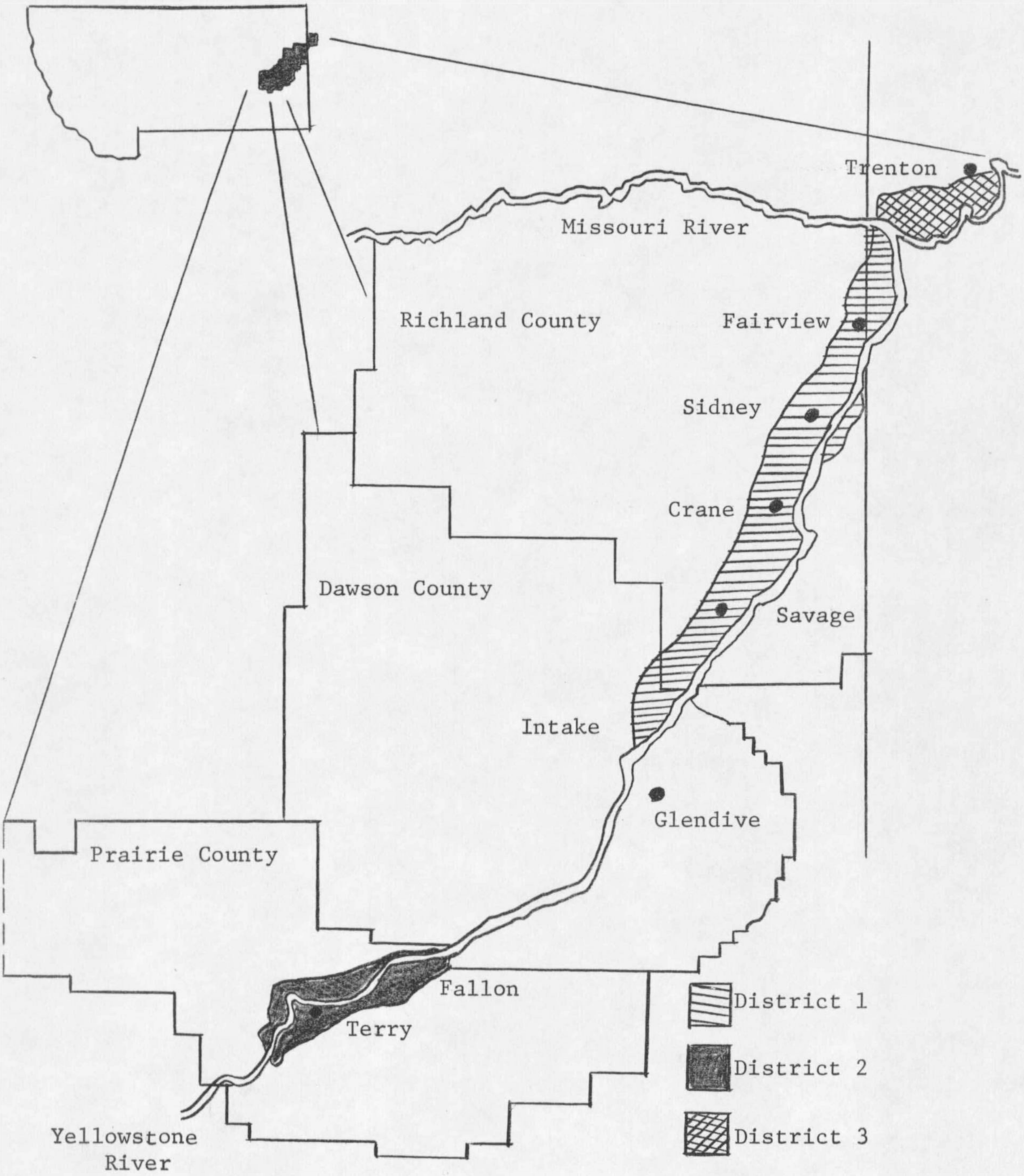

Figure 3. Regional Farm I--East Central Montana--By District.

confluence (Figure 3). These three districts of Regional Farm I constitute the Holly Sugar Company factory area with headquarters at Sidney, Montana.

Water

Sugar beets and other irrigated crops are grown within the bounds of Regional Farm I only where there are established irrigation projects. The growers under the Bureau of Reclamation's projects, Buffalo Rapids and Lower Yellowstone, secure their water from the Yellowstone River. Sugar beet growers in Williams County, North Dakota, depend upon the Missouri River for their irrigation water. There is little dependence upon rainfall to sustain irrigated cropping patterns.

Climate

The climate of Regional Farm I is characterized by low rainfall, extreme temperature ranges, cold winters, relatively low humidity, and a number of long sunny days during the growing season. The normal or long run average annual rainfall in the region is 13.16 inches, with 77 percent or 10.18 inches occurring between April and September (Table VI). The number of days in the growing season, from the last spring day recording 32 degrees Fahrenheit and the first fall day reaching 32 degrees Fahrenheit, varies from year to year. The average number of frost free days in the growing season is about 128 days. Savage, Montana, located in the center of the regional farm has recorded temperatures varying from 110 degrees Fahrenheit to 46 degrees Fahrenheit below zero, a range of 156 degrees.

The mean annual temperature at Savage, Montana, is 43.3 degrees Fahrenheit, and the mean growing season temperature is 72 degrees Fahrenheit. 1/

TABLE VI. CLIMATE DATA, REGIONAL FARM I, 1966. a/

District	Annual Normal Precipitation (Inches)	Growing Season Precipitation (Inches)	Average Number of Days Between Freezing Temperatures b/
Lower Yellowstone	13.41	10.82	125.50
Buffalo Rapids	12.36	9.56	119.45
Buford-Trenton	13.70	10.15	132.00

a/ Sources: Montana Agricultural Statistics, Montana Department of Agriculture and United States Department of Agriculture Helena, Montana, Climatological Data, Montana, Annual Summary, United States Department of Commerce, Environmental Science Services Administration, Weather Bureau, Washington, and Holly Sugar Company, Wayne Berry, Buford-Trenton District Fieldman.

b/ 32 degrees Fahrenheit

The irrigated lands contained in the narrow lower Yellowstone Valley are protected to some extent from the prevailing northwest winds. Nevertheless, during the spring some soil erosion occurs on irrigated lands within the region.

1/ Soils of Richland County, Soil Reconnaissance of Montana, Preliminary Report, Montana State College, Agriculture Experiment Station Bulletin, No. 515, Bozeman, Montana, 1955, pp. 18-22.

Soils

A preliminary soil reconnaissance was carried out in Richland County during 1965. Sixty-seven soil types, complexes, and phases were identified. Undifferentiated alluvial soils accounted for 10.75 percent of the total soil in the county. The undulating phase of Scobey loam accounted for 209 square miles (10.40 percent).

The Soil Conservation Service and the Agronomy Department at Montana State University are in the process of classifying the soils of Dawson, Prairie and other Montana counties. It appears reasonable to assume that the soils in the irrigated areas of Dawson County from Intake north to the Richland County line are similar to those that have been identified in Richland County because the areas are close together and share similar geological formations. The soil types extending southwest of Glendive into Prairie County, however, may be different.

The soils located in the prime agricultural irrigated areas of the Regional Farm consist of the Havre, Harlem, Mitchell, and Bowdoin series. These types are primarily sandy and light brown in color. Subsoils range from sandy to silty clay, to deep dense clay. The soils found in the irrigated areas of District I are primarily alluvial. Larimer soils of the tablelands and benchlands along with soils of the Farland, Savage, and Orman series form the predominant soil types in the higher elevations of the Lower Yellowstone Valley. These soils are well drained and consist of gravelly loam, gravelly sandy loam, silty clay loam and clay loam, and range in color from dark brown (Farland series) to olive grey (Orman series). 2/ The soils of District 3, (North Dakota) are similar to those of District 1. The soils appear to have been deposited by the Missouri River and they consist of loam, loam clay, and sandy loam.

Crops and Yields

The irrigated crops grown within the boundaries of Regional Farm I include sugar beets, dry edible beans, alfalfa, wheat, barley, oats, potatoes, corn for grain, sudan, sorghum, and corn for silage. All farmers interviewed in Regional Farm I grew sugar beets in 1966. The percentages of farmers growing specified crops as determined through the sampling procedure are listed in Table VII.

Crop yields within Region Farm I vary according to management practices, weather conditions, and soil types. The 1966 average yields for selected crops as well as the five-year average yields as reported by 51 farmers are recorded in Table VIII.

The irrigated crops grown in Regional Farm I are generally included in a cropping rotation plan. Cropping sequences depend on the type of crops grown, nature of the soil, and management's awareness of disease, insect, and weed problems. No one crop rotation dominated those cropping sequences reported by 51 growers. There were, however, four crop rotation patterns reported by 68 percent of all farmers within the region (Table IX).

2/ Ibid., pp. 42-83.

TABLE VII. THE NUMBER OF FARMERS GROWING SPECIFIED IRRIGATED CROPS IN REGIONAL FARM I, 1966.

	Number of Farmers Growing Crops (51 Farmers Interviewed)	Percentage of Farmers Interviewed Growing Specified Crops
Sugar beets	51	100.0
Alfalfa	47	92.1
Wheat	29	56.9
Dry Beans	27	52.9
Barley	19	37.2
Corn Silage	19	37.2
Oats	17	33.3
Corn for Grain	5	9.8
Potatoes	3	5.9
Sorghum	1	2.0
Sudan	1	2.0

TABLE VIII. YIELDS FOR SELECTED CROPS, 1966 AND FIVE YEAR (1961-66), WEIGHTED AVERAGE, REGIONAL FARM I.

Crop	Yield per Acre 1966	Yield per Acre 1961-66
Sugar beets	17.02 tons	14.95 tons
Alfalfa	3.59 tons	3.53 tons
Wheat	45.56 bushels	44.12 bushels
Dry Beans	19.13 cwt.	20.02 cwt.
Barley	63.79 bushels	68.49 bushels
Corn Silage	18.63 tons	18.26 tons
Oats	69.57 bushels	76.18 bushels
Corn for Grain	74.18 bushels	80.00 bushels
Potatoes	232.61 cwt.	260.87 cwt.

TABLE IX. REPORTED CROPPING PATTERNS USED BY GROWERS — REGIONAL FARM I, 1966.

Crop Sequence					Number of Growers Using Crop Sequence
Grain,	3 alfalfa,	grain,	beets,	grain, beets	11
Grain,	3 alfalfa,	2 beets,			9
Grain,	3 alfalfa,	beets,	beans		9
Beets,	corn ,	beans,	(Occasional alfalfa)		6
Grain,	3 alfalfa,	beets,	corn		4
Grain,	3 alfalfa,	2 beets,	corn		3
Beets,	fallow ,	beets,	wheat		2
Grain,	3 alfalfa,	3 beets,	corn		2
Grain,	3 alfalfa,	oats ,	wheat,	beets	1
Grain,	3 alfalfa,	oats ,	wheat,	beans	1
Grain,	beets,				1
Grain,	3 alfalfa,	potatoes,	beets		1
Corn ,	beets,	fallow			1

A number of farmers interviewed not only grew cash crops, but crops to be marketed in the form of livestock. Alfalfa, corn silage, sorghum, and some grain were used as livestock feed.

Livestock

Farmers in the Region I Farm raise livestock for local and eastern markets. Sidney, Montana, is the livestock marketing center of Northeast and East-Central Montana. Farmers reported eight different livestock operations on farms within the bounds of Regional Farm I. The feeding of livestock (beef, swine, and lambs) was reported by the majority of farmers (Table X). Many farmers indicated more than one type of livestock organization.

TABLE X. LIVESTOCK ENTERPRISES REPORTED BY GROWERS — REGIONAL FARM I, 1966.

Livestock Organization	Number of Farmers Reporting		Percentage of Farmers Reporting	
Beef feeding		24		47.1
Lamb feeding		14		27.4
Swine feeding		4		7.8
Winter cows on stubble		4		7.8
Beef cows for calves		16		31.3
less than 10 head	6		11.8	
more than 10, less than 20	2		4.5	
more than 20, less than 30	4		7.8	
more than 31	4		7.8	
Dairy cows for milk		12		23.5
less than 10 cows	11		21.6	
more than 10 cows	1		2.0	
Ewes and rams		5		9.8
Poultry		5		9.8

The management of livestock operations as well as cropping enterprises requires a considerable amount of labor. Family, local and migrant labor are available to carry out the farm operations.

Labor

The labor required to carry out farming practices in Regional Farm I is dependent upon the season of the year. The family farm unit is the basic source of labor. Family labor is supplemented by workers indigeneous to the Sidney and Glendive areas. High school age boys make up a large portion of the summer labor force.

Some crops require specially trained workers in order to insure high yields. Sugar beets and occasionally dry beans require skilled people to thin the crop and hoe weeds. Laborers used in these operations are migrant domestics from Texas.

Sugar Beet Supply Model: Regional Farm I

The linear programming sugar beet supply response model for Regional Farm I consists of alternative cropping sequences (activities), resources that limit sugar beet production (restrictions), and appropriate input-output coefficients. All of the constituents of the model are projected to 1980.

Twenty cropping pattern alternatives are the activities of the Regional Farm I model (Table XI). These crop rotations are the alternatives reported by farmers of Region I and by the Montana Agricultural Experiment Station. 3/ The cropping alternatives reported for 1966 are assumed to be the cropping sequence alternatives in 1980.

The net revenue coefficient indicating the profitableness of the cropping sequences reflects 1980 costs and returns. 4/ Each net revenue coefficient includes the cost of water for a given district as well as the appropriate crop yields for a given land type within the district. The model has been specified in such a way that each crop rotation can be produced within each district of the region on all land

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3/ W. E. Larson, et. al., Irrigated Crop Rotations, Montana Agricultural Experimentation Bulletin No. 535, January, 1958.

4/ See Chapter III, page 56.

types within the district. Crop rotations including sugar beets are not grown, for the most part, on Land Type 4 in any district, since it is not capable of economically supporting sugar beets. 5/

TABLE XI. CROP ROTATION ALTERNATIVES - REGIONAL FARM I, 1980.

Rotation Number	Cropping Sequence						Number of years
1	Barley,	3 alfalfa,	oats	, wheat	, beets		7
2	Oats ,	3 alfalfa,	beets	, beans			6
3	Barley,	3 alfalfa,	beets	, beets			6
4	Oats ,	3 alfalfa,	corn sil	, beets			6
5	Barley,	3 alfalfa,	oats	, beets	, wheat	, beets	8
6	Beets ,	wheat ,	beans				3
7	Barley,	3 alfalfa,	wheat	, beets	, beans		7
8	Beets ,	corn grain,	beans				3
9	Barley,	3 alfalfa,	beets	, beets	, corn sil		7
10	Oats ,	3 alfalfa,	potatoes	, beets			6
11	Oats ,	3 alfalfa,	potatoes				5
12	Barley,	3 alfalfa,	beans				5
13	Oats ,	corn sil ,	beans				3
14	Potatoes,	corn grain,	barley				3
15	Barley,	3 alfalfa,	potatoes	, corn sil,	corn sil		7
16	Oats ,	3 alfalfa,	beans	, beans			6
17	Barley,	3 alfalfa,	beans	, wheat	, beans		7
18	Potatoes,	beans ,	corn sil				3
19	Barley,	3 alfalfa,	oats	, wheat	, beans		7
20	Oats ,	3 alfalfa,	corn grain,	beans	, corn sil		7

Regional Farm I contained 81,269 acres of irrigated land in 1966. By 1980, it is expected that 3,000 additional irrigated acres of land will be available for crop production through irrigation developments completed by

5/ Land 4 in some districts is capable of supporting sugar beets. The Soil Conservation Service has identified the areas where Land 4 can support sugar beets and these areas have not been restricted in the model.

the Bureau of Reclamation. 6/ Also, state irrigation projects are expected to add 18,162 acres of irrigated land to the Regional Farm I inventory. 7/ Therefore, by 1980 approximately 102,431 acres of irrigated land will be available for crop production (Table XII). Sugar beet production could be carried out on 98,127 acres of this land.

Regional Supply Response

Three sugar beet supply estimates were made: (1) regional farm response, (2) regional farm response including a land use restriction, and (3) typical farm response. The supply estimates for sugar beets were made by varying the price of beets from $14.00 per ton to $21.50 per ton, holding the prices of other competing crops constant.

Model I: Under the conditions of the model it was determined that there would be no sugar beet production in Regional Farm I in 1980. Those rotations that contained potatoes completely dominated 1980 crop production. Rotation 14 and 18 which contained potatoes dominated all optimum solutions. Although the solution suggests that a large number of irrigated acres in Regional Farm I should be planted to potatoes, few potatoes have

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6/ Personal correspondence from B. E. Garlinghouse, Chief, Irrigation Division, Bureau of Reclamation, Region 6, United States Department of Interior, Great Falls, Montana, June 26, 1968.

7/ State Water Conservation Board, Preliminary Report, Water Needs of Montana, February 1962.

TABLE XII. INVENTORY OF LAND IN REGIONAL FARM I, BY DISTRICT, LAND CLASS, AND NEW PROJECTS, 1980.

District	Land Classes: Class 1	Class 2	Class 3	Class 4	Totals
District 1					
1966 inventory	20,962	16,469	854	419	38,704
State projects, 1980 a/	5,238	4,171	194	97	9,700
Bur. of Reclam. 1980 a/	810	645	30	15	1,500
Subtotal	27,010	21,285	1,078	531	49,904
District 2					
1966 inventory	14,531	10,690	4,213	2,558	31,992
State projects, 1980 a/	3,554	2,625	1,038	645	7,862
Bur. of Reclam. 1980 a/	678	501	198	123	1,500
Subtotal	18,763	13,816	5,449	3,326	41,354
District 3					
1966 inventory	2,305	5,028	2,793	447	10,573
State projects, 1980 a/	600	0	0	0	600
Bur. of Reclam. 1980 a/	0	0	0	0	0
Subtotal	2,905	5,028	2,793	447	11,173
Grand total	48,678	40,129	9,320	4,304	102,431

a/ State and Bureau of Reclamation Projects that will be completed by 1980.

been grown within the region (Table XIII). Limited potato production within the regional farm occurs because of drastically fluctuating potato prices. The average Montana potato price from 1956 to 1966 was $2.96 per hundredweight. However, the range of the prices received for potatoes over the same period of time was $1.86 per hundredweight to $6.23 per hundredweight. Potatoes appear to be a high risk crop compared to alternatives within the region because of wide price fluctuations.

TABLE XIII. POTATO PRODUCTION - REGIONAL FARM I, 1957-1967. a/

Year	Potatoes Harvested-Regional Farm I	Total Montana Potatoes Production	Regional Farm I Percent of Total Montana Sugar Production
	(acres)	(acres)	
1957	240	7,880	3.05
1958	240	8,180	2.93
1959	250	8,140	3.07
1960	178	7,460	2.39
1961	243	7,381	3.29
1962	210	7,150	2.94
1963	189	7,254	2.61
1964	139	7,049	1.97
1965	276	7,175	3.85
1966	325	7,384	4.40
1967	308	8,000	3.85
Average (1957-67)	236	7,550	3.12

a/ Source: United States Department of Agriculture, Montana Department of Agriculture, Statistical Reporting Service, Montana Agricultural Statistics, Volumes VII - XI, Potatoes.

Model II: Individual grower preferences do not dictate that two or three cropping sequences will actually be practiced as the results of the previous model suggest. Therefore, an additional supply response was made by placing a land use restriction on each crop rotation in the objective function. The land use restriction meant that no one rotation would be allowed to use more than one-fifth of the land available in a given district. It is thought that if more than one-fifth of the land were to be planted to sugar beets, yields would diminish over time because of insect, disease, and soil depletion problems.

The sugar beet supply estimate made with the land use restrictions are shown in Table XIV and Figure 4.

TABLE XIV. SUGAR BEET SUPPLY RESPONSE BY DISTRICT IN 1980 FOR REGIONAL FARM I, INCLUDING LAND USE LIMITS.

Price per Ton	District 1	District 2	District 3	Total
(Dollars)	(Acres)	(Acres)	(Acres)	(Acres)
14.00	1,297	1,724	466	3,487
14.50	1,297	1,724	466	3,487
15.00	1,297	1,724	466	3,487
15.50	1,298	1,724	466	3,488
16.00	1,298	1,724	466	3,488
16.50	1,298	1,724	466	3,488
17.00	1,299	1,724	466	3,488
17.50	1,299	3,287	466	5,052
18.00	1,342	3,564	503	5,409
18.50	1,342	3,564	503	5,409
19.00	1,343	3,564	503	5,410
19.50	2,125	3,564	503	6,192
20.00	2,125	3,564	503	6,192
20.50	2,125	3,564	503	6,192
21.00	4,486	4,156	755	9,397
21.50	4,696	5,309	1,416	11,421

In this bounded model, Rotations 10, 14 and 18, which included potatoes, entered the solution at $14 per ton for beets and remained through the final solution. Potatoes are the most important competitor for sugar beet resources in Region I. Rotations 6, 8, 11 and 15 also were included at various stages in the supply estimate for sugar beets. Rotations 6 and 8 included beets and eventually replaced Rotations 11 and 15. At the 1980 projected price per ton of sugar beets, the optimal rotations are 6, 10, 11, 14 and 18 which

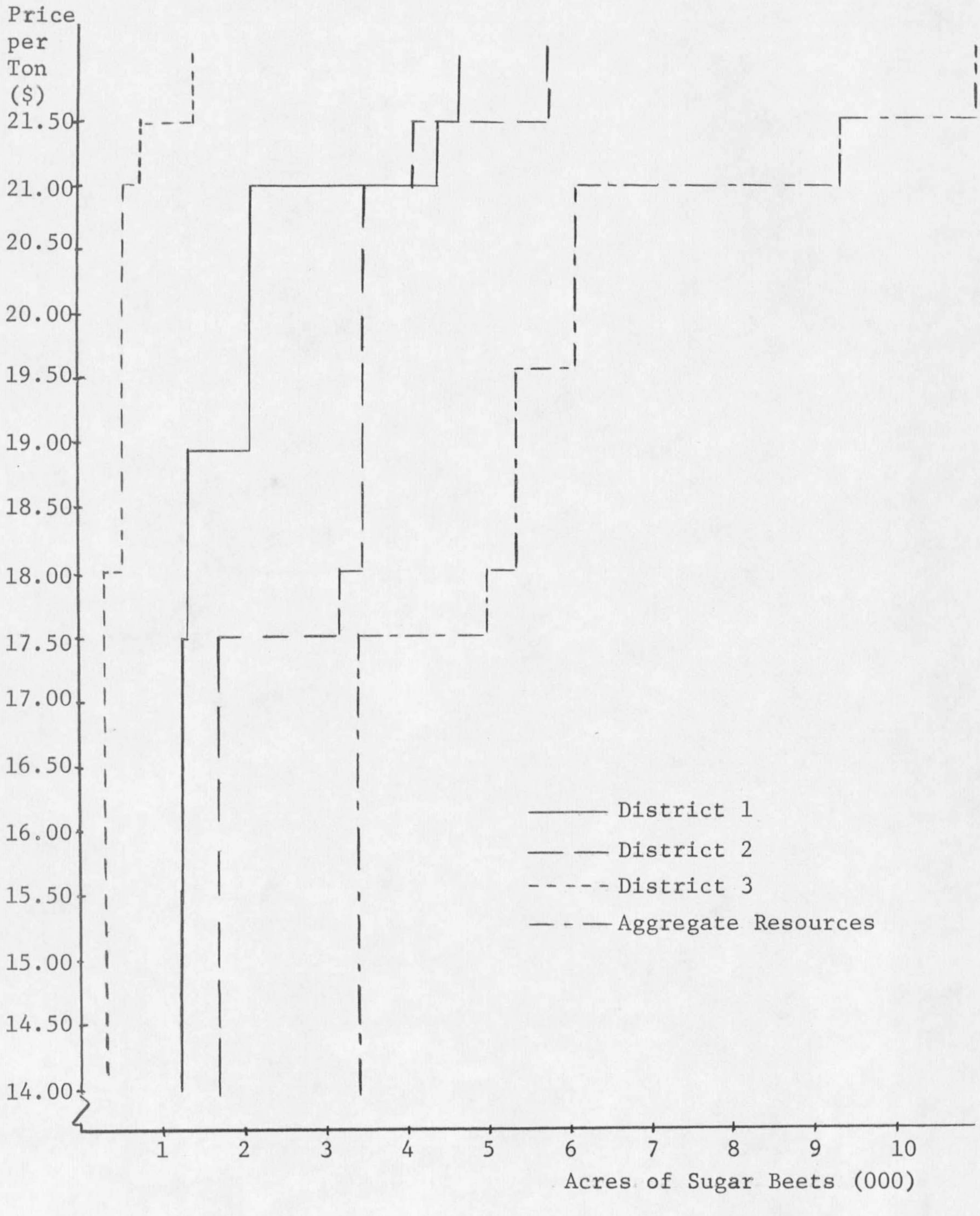

Figure 4. Supply Response by District in 180 for Regional Farm I Including Land Use Limits.

include 5,052 acres of sugar beets. However, at beet prices near $20.00 per ton, sugar beet cropping sequences will replace those containing potatoes.

Model III: A long run supply estimate for sugar beets was made by using typical farms as the responding unit. Three typical farms were determined to be representative of the farms within Regional Farm I. The farms chosen typify three farm size classifications, 146, 244, and 326 irrigated acre farms.

Each representative farm consisted of four land types. The number of acres of each land type on each farm was determined by measuring the percent of each land type available in the districts of the Regional Farm model; i.e., Land 1 represented 54 percent of all land available for crop production in District 1 (Table XV).

The number of hours of family labor per typical farm was determined by a general formula. 8/ The formula consists of 177 working days, 10 hour days, and the number of family laborers per farm. Table XVI reports the number of family hours available per typical farm in Region I for 1980.

Each representative farm within each district of Region I was assumed to have equal opportunity to select any combination of the rotation patterns defined for the region in order to maximize profits.

8/ See page 60 for the labor computation.

TABLE XV. THE NUMBER OF ACRES OF IRRIGATED LAND TYPES ON THREE TYPICAL FARMS, REGION I, 1980.

Land Types By District	Percent Land Type of Total Land	Typical Farm Size by Land Types (146 acres)	(244 acres)	(326 acres)
District 1				
Land 1	54.1	76	132	176
Land 2	42.7	62	104	139
Land 3	2.2	3	5	7
Land 4	1.0	2	3	4
District 2				
Land 1	45.5	66	111	148
Land 2	33.4	49	81	109
Land 3	13.2	19	32	43
Land 4	8.0	12	20	26
District 3				
Land 1	26.0	38	63	85
Land 2	45.0	66	110	147
Land 3	25.0	36	61	81
Land 4	4.0	6	10	13

TABLE XVI. HOURS OF FAMILY LABOR AVAILABLE ON TYPICAL FARMS, 1980.

Farm Size	Family Workers per Farm	Number of Hours Available for Crop Production 1980
146	1.44	2,544
244	1.54	2,726
326	1.56	2,761

Using this data, a supply response for each typical farm within each of the three districts of Regional Farm I was determined. The resulting sugar beet supply estimates per representative farm were expanded by the number of farms of each size group expected to be in production during 1980 (Table XVII). The expanded representative farm sugar beet supply estimates were aggregated to form the regional long run supply response for sugar beets (Table XVIII and Figure 5).

TABLE XVII. THE NUMBER OF TYPICAL FARMS IN 1980, EAST-CENTRAL REGION.

Typical Farm Size (Acres)	Farms 1966 (Percentage)	Number of Farms Expected by Size Groups 1980
146	17.6	87
244	56.9	285
326	25.2	128
TOTALS	100.0	500

At $17.50 per ton of sugar beets, 3,937 acres of sugar beets should be produced by the farmers in the East-Central Region of Montana. Also, 244-acre farms will produce 2,166 acres of beets; 326-acre farms 1,357 acres; and 146-acre farms 414 acres of sugar beets in 1980.

Summary

Supply response estimates for a regional farm and typical farms were made in Chapter IV. At sugar beet prices above $15.50 per ton the typical

TABLE XVIII. SUGAR BEET SUPPLY RESPONSE BY TYPICAL FARMS IN 1980 FOR REGION I.

Price per Ton	Farm 1 (146 acres)	Farm 2 (244 acres)	Farm 3 (326 acres)	TOTAL
(Dollars	(acres)	(acres)	(acres)	(acres)
14.00	326	1,710	1,062	3,098
14.50	326	1,710	1,062	3,098
15.00	376	1,995	1,229	3,602
15.50	414	2.166	1,357	3,937
16.00	414	2,166	1,357	3,937
16.50	414	2,166	1,357	3,937
17.00	414	2,166	1,357	3,937
17.50	414	2,166	1,357	3,937
18.00	528	2,736	1,702	4,966
18.50	1,258	6,726	4,096	12,080
19.00	1,813	9,776	5,926	17,515
19.50	1,936	10,346	6,221	18,503
20.00	1,936	10,346	6,221	18,503
20.50	2,226	11,970	7,206	21,402
21.00	2,226	11,970	7,206	21,402
21.50	2,226	11,970	7,206	21,402

farm supply response was greater than the regional estimates. The only exception was at beet prices ranging from $17.50 to $18.50 per ton. At the equilibrium price in 1980 the East Central region growers should produce between 3,937 and 5,052 acres of sugar beets (Table XIX and Figure 6). The results of each model show that potatoes followed by sugar beets are the chief competition for agricultural resources in this region.

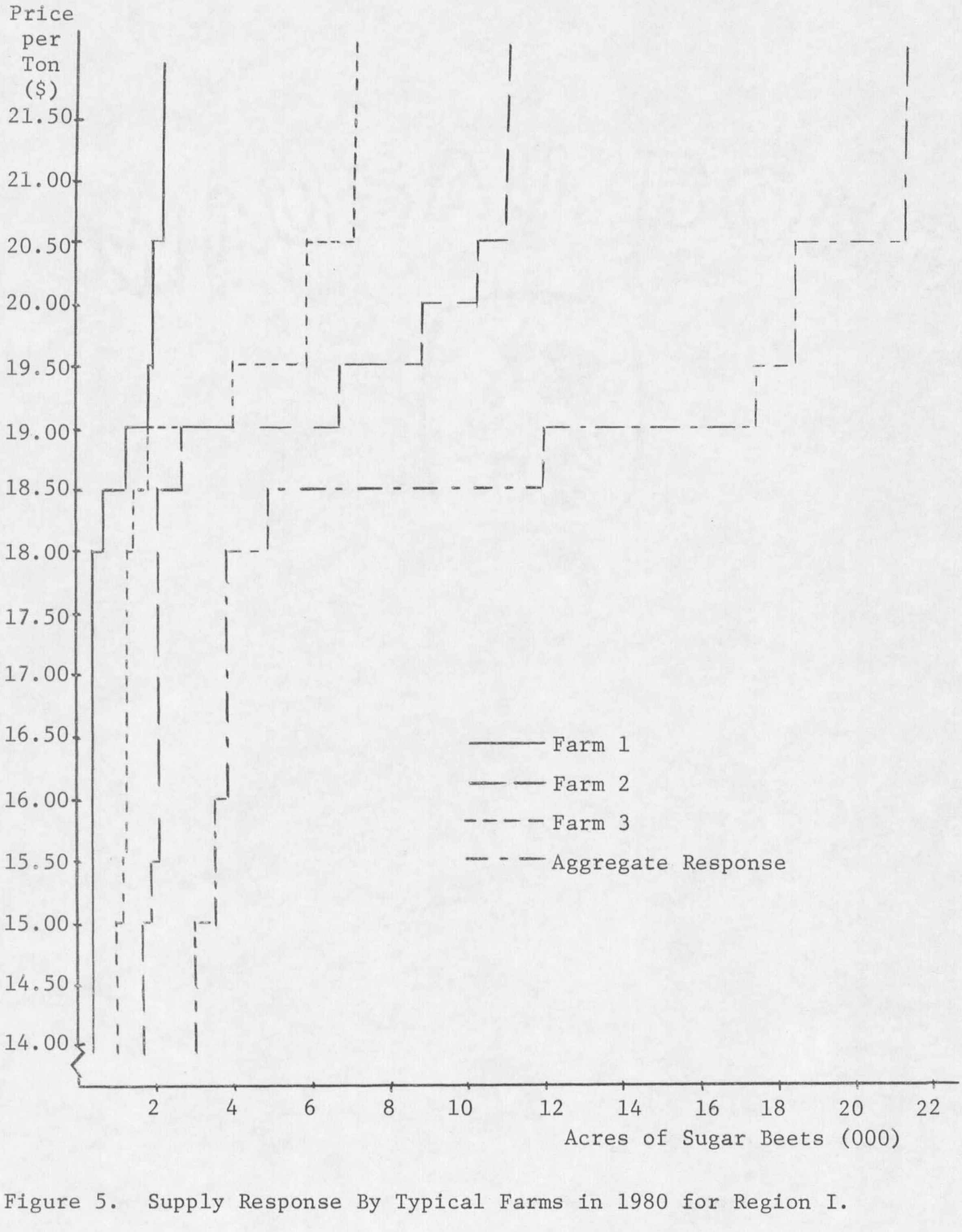

Figure 5. Supply Response By Typical Farms in 1980 for Region I.

TABLE XIX. COMPARISON OF THREE ALTERNATIVE SUGAR BEET SUPPLY RESPONSES FOR THE EAST-CENTRAL REGION OF MONTANA 1980.

Price per Ton for Sugar Beets	Model 1 Region	Model 2 Region a/	Model 3 Typical Farm
(Dollars)	(acres)	(acres)	(acres)
14.00	0	3,487	3,098
14.50	0	3,487	3,098
15.00	0	3,487	3,602
15.50	0	3,488	3,937
16.00	0	3,488	3,937
16.50	0	3,488	3,937
17.00	0	3,488	3,937
17.50	0	5,052	3,937
18.00	0	5,409	4,966
18.50	0	5,409	12,080
19.00	0	5,410	17,515
19.50	0	6,192	18.503
20.00	0	6,192	18,503
20.50	0	6,192	21,402
21.00	0	9,397	21,402
21.50	0	11,421	21,402

a/ Includes land use limits.

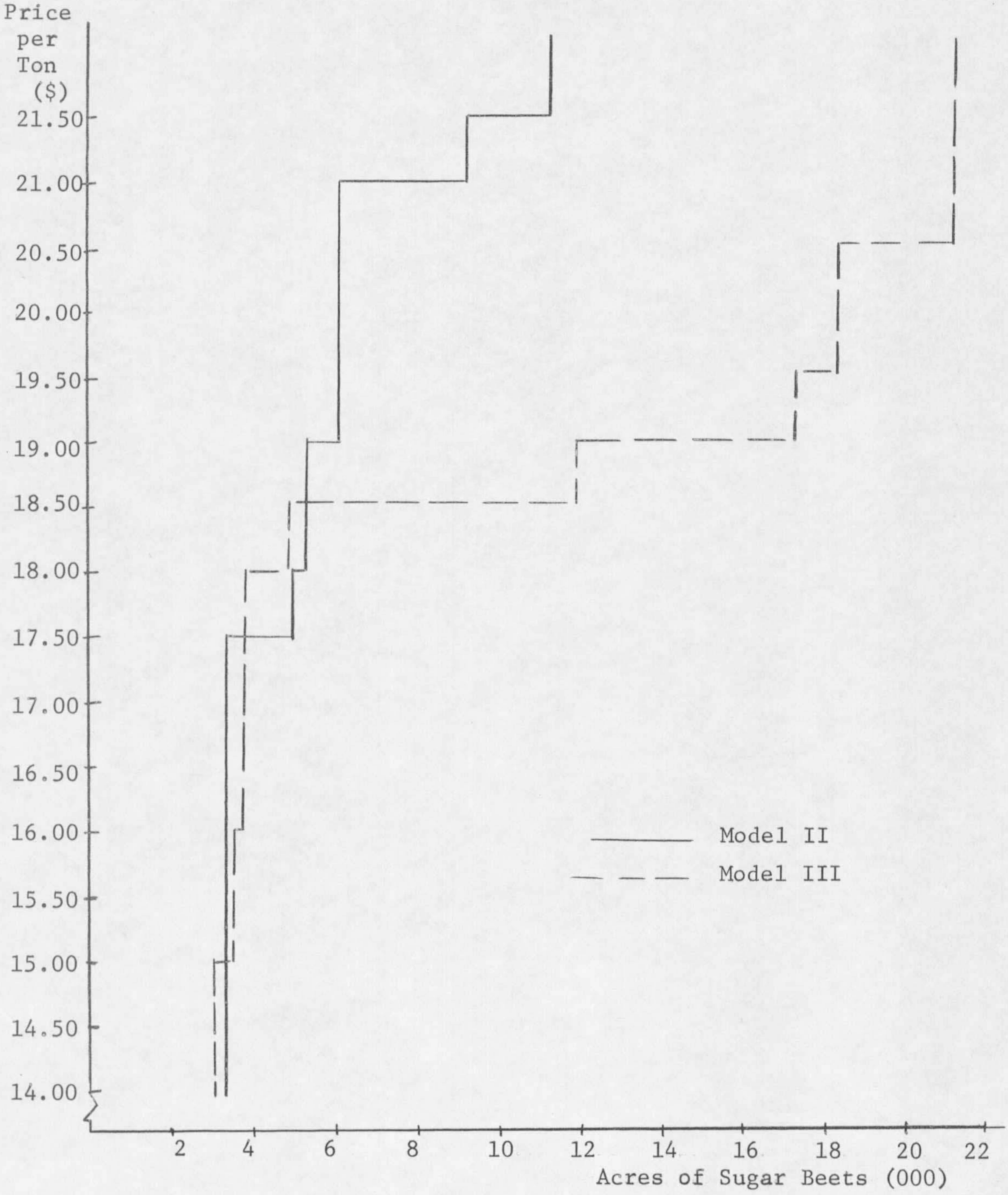

Figure 6. Comparison of Three Alternative Sugar Beet Supply Responses for the East Central Region of Montana, 1980.

CHAPTER V

SUGAR BEET PRODUCTION RESPONSE--SOUTHEASTERN REGION

This chapter will describe the southeastern sugar beet production area in Montana. The 1980 sugar beet supply estimates for the region are presented, including regional and typical farm comparisons.

Area Under Study

The southeastern sugar beet producing region consists of four Montana counties. These counties are (1) Custer, (2) Rosebud, (3) Treasure, and (4) Big Horn. The general boundary of the sugar beet producing area is formed by two river valleys, the Yellowstone River Valley from Hysham to Miles City and the Big Horn River Valley from St. Xavier, in the south, to Hysham in the north.

Regional Farm II is subdivided into two districts based on the general sources of water. Sugar beet growers in Big Horn and Treasure counties, who depend upon the Big Horn and Little Big Horn Rivers for irrigation water make up District 1. Those irrigated areas near the Yellowstone River in Treasure, Rosebud and Custer counties are included as District 2 of Regional Farm II (Figure 6).

The total irrigated area of Regional Farm II encompasses the Holly Sugar Company factory district at Hardin. A portion of Wyoming is also included in the factory district. However, the sugar beet growing areas in Wyoming are not included in this analysis.

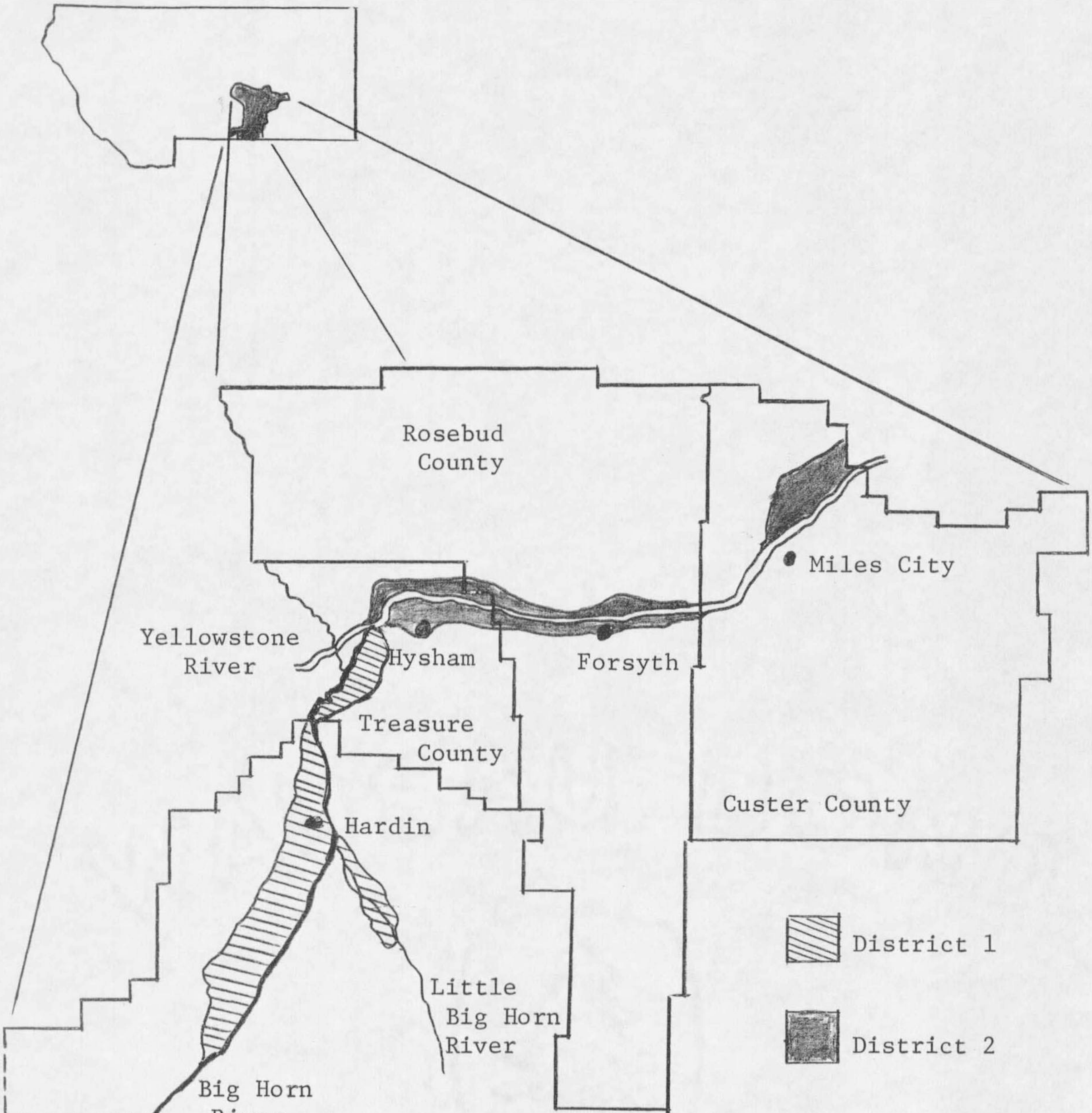

Figure 7. Regional Farm II--Southeastern Montana--By District

Water

Farmers in the region depend upon state irrigation projects that use Big Horn, Little Big Horn, and Yellowstone River water. Growers were associated with more than 15 private ditch companies that supply water from the main sources. The Kinsey Irrigation Project located near Miles City on the Yellowstone River was developed as a resettlement project in the 1930's by the Federal Government.

Climate

The climate of the irrigated valleys of Regional Farm II is similar to the climate of Regional Farm I (East-Central Montana). Hot summer days, cold winters, semi-arid conditions with some wind, many long sunshiny days, and relative low humidity characterize Region II. The average rainfall in the region is 12.19 inches with an average of 71 percent or 8.60 inches occurring during the growing season (Table XX).

The number of days in the growing season varies within the bounds of Regional Farm II. The number of days in the growing season of District 1 (Big Horn County) vary from 122 days in the north to 135 days in the south. The number of days in the growing season of District 2 ranges from 121 at Hysham to 155 days at Miles City. 1/

1/ Soil Survey, The Big Horn Valley Area of Montana, U. S. D. A, in cooperation with the Montana Agricultural Experiment Station, Series 1938, No. 6, January 1945, p. 7 and Soil Survey the Middle Yellowstone Valley Area Montana, U. S. D. A. in cooperation with the Montana Agricultural Experiment Station, Series 1933, No. 33, Aug. 1940, pp. 3-4. pp. 3-4.

TABLE XX. CLIMATE DATA, REGIONAL FARM II. a/

District	Annual Normal Precipitation	Growing Season Precipitation	Average Number of Days Between Freezing Temperatures b/
	(inches)	(inches)	
(1) Big Horn	11.58	8.22	128
(2) Mid-Yellowstone	12.50	8.80	137

a/ Source: Soil Survey, The Middle Yellowstone Valley Area, Montana U. S. D. A., Series 1933, No. 33, August 1940; Soil Survey, The Big Horn Valley Area, Montana, U. S. D. A., Series 1938, No. 6, January 1945; Soil Survey, Treasure County, Montana, U. S. D. A., SCS, Series 1957, No. 22, February 1967.

b/ 32 degrees Fahrenheit

Temperatures in the Regional Farm vary from 110 degrees Fahrenheit to 48 degrees below zero. The average July temperatures is near 80 degrees Fahrenheit.

Winds are common throughout the area; however, very little crop damage is caused by the prevailing winds. Chinook or Foehn winds, that are fairly warm, occur often during the winter months.

Soils

The soils in the irrigated portions of District 1 are primarily alluvial having been deposited by the Big Horn and Little Big Horn Rivers. The bottom lands are made up of Havre, Banks, and Banks-Havre soil series. These soils range in color from moderately dark brown to brownish gray and for the most part are level. Nearly 27 percent of the soils in District 1 are of the Havre and Banks series. Other important soils series in the district are Fort Collins, Billings, Glendive, Cherry Neville and Cushman. These soils are gently sloped and are found on terraces. Color ranges from red brown (Neville) to dark grayish brown (Cushman). 3/

District 2 near the Yellowstone River consists of Havre, Banks, Harlem, and Bowdoin soils. Havre soils represent 23 percent of the irrigated lands of District 2. The Havre soils are made up of sandy, silt, and clay loam types and are very important to irrigated crop production. 4/

Crops and Yields

The important irrigated crops that are grown in Regional Farm II are sugar beets, alfalfa, corn silage, oats, wheat, barley, and irrigated pasture. All farmers interviewed in Regional II grew sugar beets during 1966. The percentage of farmers growing specified irrigated crops in Regional Farm II are listed in Table XXI.

The yields of irrigated crops in Regional Farm II depend upon management practices, soil types water and weather conditions. The average 1966 yields for irrigated crops in Regional Farm II are reported in Table XXII along with five year average yields.

3/ Soil Survey--Bighorn Valley, op. cit., pp. 18-20.

4/ Soil Survey--Middle Yellowstone Valley, op. cit., pp. 15-18. Also Soil Survey Treasure County, U. S. D. A., SCS, Montana Agricultural Experiment Station, Series 1957, No. 22, February 1967, pp. 5-35.

TABLE XXI. THE NUMBER OF FARMERS GROWING SPECIFIED IRRIGATED CROPS IN REGIONAL FARM II, 1966.

Irrigated Crop	Number of Farmers Growing Crop (28 Farmers Interviewed)	Percentage of Farmers Interviewed Growing Specified Crop
Sugar beets	28	100.0
Alfalfa	27	96.4
Irrigated Pasture	24	85.7
Dry Pasture	19	67.8
Wheat	18	64.2
Oats	13	46.4
Barley	12	42.8
Corn Silage	11	39.2
Grass Hay	5	17.8
Beans	5	17.8
Corn Grain	4	14.2
Sorghum	2	7.1
Mixed Hay	1	3.5
Clover	1	3.5

TABLE XXII. YIELDS FOR SELECTED CROPS, 1966 AND FIVE YEAR (1961-1966), WEIGHTED AVERAGE --REGIONAL FARM II.

Crop	Yield per Acre 1966	Yield per Acre 1961-1966
Sugar beets	17.45 tons	15.03 tons
Alfalfa	3.37 tons	2.60 tons
Wheat	39.8 bushels	37.9 bushels
Oats	81.3 bushels	77.8 bushels
Barley	51.5 bushels	49.7 bushels
Corn silage	18.0 tons	16.7 tons
Grass hay	2.0 tons	2.0 tons
Beans	2.2 cwt.	2.2 cwt.
Corn grain	NA	NA

Farmers growing irrigated crops in Regional Farm II, also generally follow a cropping pattern. Crop rotations are used to minimize disease and insect problems in cash crops. There were 13 cropping sequences reported by 28 growers in Regional Farm II. The first three crop rotations reported in Table XXIII were suggested by 46 percent of the farmers interviewed.

TABLE XXIII. REPORTED CROPPING PATTERNS USED BY GROWERS--REGIONAL FARM II, 1966.

Cropping Sequence						Number of Growers Using Cropping Sequence
grain ,	3 alfalfa,	corn sil,	beets,			5
grain ,	3 alfalfa,	beets ,	beets,	corn sil,		4
grain ,	3 alfalfa,	grain ,	beets,	grain ,	beets	4
grain ,	3 alfalfa,	beets ,	beets,	beets		3
grain ,	3 alfalfa,	beets ,	beets,	beans		2
clover ,	grain ,	beets ,	beets,			2
corn ,	oats ,	beets ,				1
grain ,	3 alfalfa,	beets ,	beets,	beets ,	clover	1
beets ,	beans ,	beets ,	beans			1
beets continuous						1
corn sil,	wheat ,	beets				1
no rotation specified						3

A number of crops in Regional Farm II are marketed in the form of livestock. Alfalfa, sugar beet tops, corn silage, and irrigated pasture were the most commonly reported roughages used for feed.

Livestock

Farmers on irrigated farms in Regional Farm II reported eight livestock operations that were supplementary to irrigated crops, (Table XXIV).

TABLE XXIV. LIVESTOCK ENTERPRISES REPORTED BY FARMERS, REGIONAL FARM II, 1966.

Livestock Organization		Number of Farmers Reporting		Percentage of Farmers Reporting
Beef feeding		22		78.5
Lamb feeding		7		25.0
Swine feeding		2		7.1
Beef cows for calves		21		75.0
less than 10 head	3		10.7	
more than 10, less than 20	5		17.8	
more than 20, less than 30	5		17.8	
more than 30	8		28.5	
Dairy cows for milk		6		21.4
less than 10 head	6		21.4	
Swine for pigs		8		28.5
Poultry		10		35.7
Ewes and Rams		8		28.5

A considerable amount of labor is required to operate livestock and cropping operations on irrigated farms. Family farms, local communities, and the sugar company are the sources of agricultural workers in Regional Farm II.

Labor

Family farm labor is the most important working force on farms in Regional Farm II. Additional labor is hired depending upon the types of crops grown and the season of the year. Skilled labor is required to weed and in some cases thin sugar beets. Labor required for the sugar beet crop migrates from the southern states during the early summer months.

Sugar Beet Supply Model: Regional Farm II

The linear programming model used to estimate a long run sugar beet supply response for Region II has been specified according to the conditions that exist in the Region. The activities of the model are cropping sequences that are thought to reflect grower cropping preferences in 1980. Further, resources that limit sugar beet production are included along with appropriate input-output coefficients.

Fourteen cropping sequences have been selected to typify alternative ways of combining crops for the purpose of maximizing grower profits (Table XXV). The rotations represent the crop sequences reported by growers as well as experimental cropping patterns tested at the Huntley Experiment Station. 6/

The profitableness of the 14 cropping sequences was determined for 1980. 7/ Each crop rotation net revenue coefficient reflected the cost of water of the two districts in the region. The crop yields for a given land type in each district are also reflected in the net revenue coefficients. The Regional Farm II model has been designed so that each crop rotation could be grown on each of four land types found in two districts. Those cropping patterns consisting of sugar beets are limited to

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6/ Larsen, Irrigated Crop Rotations, op. cit.

7/ See page 56.

TABLE XXV. CROP ROTATION ALTERNATIVES-REGIONAL FARM II, 1980.

Rotation Number	Cropping Sequence	Number of Years
1	Barley, 3 alfalfa, corn sil, beets	6
2	Barley, 3 alfalfa, beets, beets, corn sil	7
3	Oats, 3 alfalfa, wheat, beets, wheat, beets	8
4	Corn Sil, wheat, beets, beets	4
5	Oats, 3 alfalfa, beets, beets, beets	7
6	Corn Sil, oats, beets,	3
7	Oats, 3 alfalfa, corn sil, beets	6
8	Barley, 3 alfalfa, corn sil, corn Gr, beans	7
9	Barley, 3 alfalfa, potatoes, beans	6
10	Oats, 3 alfalfa, corn Gr, corn sil, corn sil	7
11	Barley, 3 alfalfa, corn sil, wheat, clover	7
12	Corn Gr, wheat, wheat, corn	4
13	Corn Sil, oats, beans	6
14	Oats, 3 alfalfa, corn sil, beans	6

Land Types 1-3. Land Type 4 is in most cases of a quality that would not insure economic yields for sugar beets under normal management procedures 8/

Regional Farm II contained 135,319 irrigated acres of land in 1966. It is expected that 102,809 additional acres of irrigated land will be in production by 1980 (Table XXVI). The new acreage expected by 1980 consists of the development of new state irrigation projects as well as Bureau of Reclamation projects. State projects will add 44,309 acres 9/ whereas, the Bureau of Reclamation is expected to add 10,500 irrigated acres of

8/ Land 4 in some cases is capable of supporting sugar beets. The Soil Conservation Service has identified the amount of Land 4 that could support sugar beets.

9/ State Water Conservation Board, Preliminary Report 1962, op. cit.

TABLE XXVI. INVENTORY OF LAND IN REGIONAL FARM II, BY DISTRICT, LAND CLASS, AND NEW IRRIGATION PROJECTS, 1980.

District	Land Classes				
	Class 1	Class 2	Class 3	Class 4	Total
	(acres)				
District 1					
1966 inventory	25,965	29,834	2,604	4,372	62,775
State projects 1980 a/	4,674	5,415	4,788	832	15,709
Bur. of Reclam. 1980 a/	2,050	2,375	210	365	5,000
Yellowtail 1980 b/	19,680	22,800	2,016	3,504	48,000
Subtotal	52,369	60,424	9,618	9,073	131,484
District 2					
1966 inventory	41,392	18,523	3,796	8,833	72,544
State projects 1980 a/	16,302	7,293	1,516	3,489	28,600
Bur. of Reclam. 1980 a/	3,134	1,403	292	671	5,500
Subtotal	60,828	27,219	5,604	12,993	106,644
Totals	113,197	87,643	15,222	22,066	238,128

a/ State and Bureau of Reclamation projects are expected to be completed by 1980.

b/ Yellowtail Dam has been constructed. However, the irrigation project has not been completed.

land to the inventory. 10/ Also, it is possible that an additional 48,000 acres of land will be under irrigation as a result of the Yellowtail Dam and the Hardin Irrigation Unit. 11/ Therefore, sugar beet production could

10/ See footnote number 6, page 75

11/ Helmer Holje, et. al., The Hardin Irrigation Unit, Montana Agricultural Experiment Station Circular No. 244, March 1966, p. 4. This source reported 43,550 additional irrigated acres. However, 48,000 additional irrigated acres was used in the model based on conversations with the Holly Sugar Company management at Hardin during 1968.

be carried out on approximately 216,062 acres in 1980 within the boundaries of Region II.

Supply Response

The following three response models for the region were developed: (1) regional farm response, (2) regional farm response including specific land use restrictions and (3) typical farm response.

Model I: The supply of sugar beets expected to be grown in the southeastern regional farm during 1980 at $17.50 per ton is 109,248 acres. Of the 238,128 acres of land available for sugar beet production, 45 percent should be planted to sugar beets in 1980 (Table XXVII and Figure 8). The supply response in District 1 (Big Horn County) is 60,026 acres of sugar beets or 10,804 more acres of beets than the supply response of District 2.

The expected regional sugar beet supply response at $17.00 per ton was 8,828 acres. By increasing the price of beets to $17.50 per ton an additional 100,000 acres of beets whould be planted. With sugar beets at $17.00 per ton Rotations 4, 9, and 14 were in the optimum solution. Crop Rotation 9 was the dominate activity. Rotation 9 includes barley, alfalfa, potatoes and beans. Rotation 4, which consists of corn silage, wheat, and two years of sugar beets, replaced Rotation 9 in the optimum solution when the beet price was increased from $17.00 to $17.50 per ton. When the sugar beet price was increased to $19.00 per ton, only those cropping sequence activities containing sugar beets were in the profit maximizing solution.

Under the conditions of the model, 45 percent of all available irrigable land in the southeastern region would be planted to sugar beets.

TABLE XXVII. SUGAR BEET SUPPLY RESPONSE BY DISTRICT IN 1980 FOR REGIONAL FARM II.

Price per Ton	Supply Response		
	District 1	District 2	Totals
Dollars	(Acres)	(Acres)	(Acres)
$14.00	0	0	0
14.50	0	0	0
15.00	0	0	0
15.50	0	0	0
16.00	3,630	5,198	8,828
16.50	3,630	5,198	8,828
17.00	3,630	5,198	8,828
17.50	60,026	49,222	109,248
18.00	60,026	49,222	109,248
18.50	64,835	52,024	116,869
19.00	65,612	53,137	118,759
19.50	65,612	53,137	118,759
20.00	65,612	53,137	118,759
20.50	65,612	53,137	118,759
21.00	65,612	53,137	118,759
21.50	65,612	53,137	118,759

The solution suggested is probable but not likely because of disease and insect problems. In order to avoid these problems, not more than 1/5 to 1/4 of the land should be planted to sugar beets.

Model II: A further restriction was placed on each cropping sequence that contained sugar beets. No more than 1/5 of any land type within each district was allowed to be used for sugar beet production. Based on the upper limit revision a 1980 sugar beet supply response was estimated for Regional Farm II (Table XXVIII and Figure 9).

At the projected 1980 sugar beet price ($17.50 per ton) it has been estimated that 71,219 acres of beets would be produced representing about

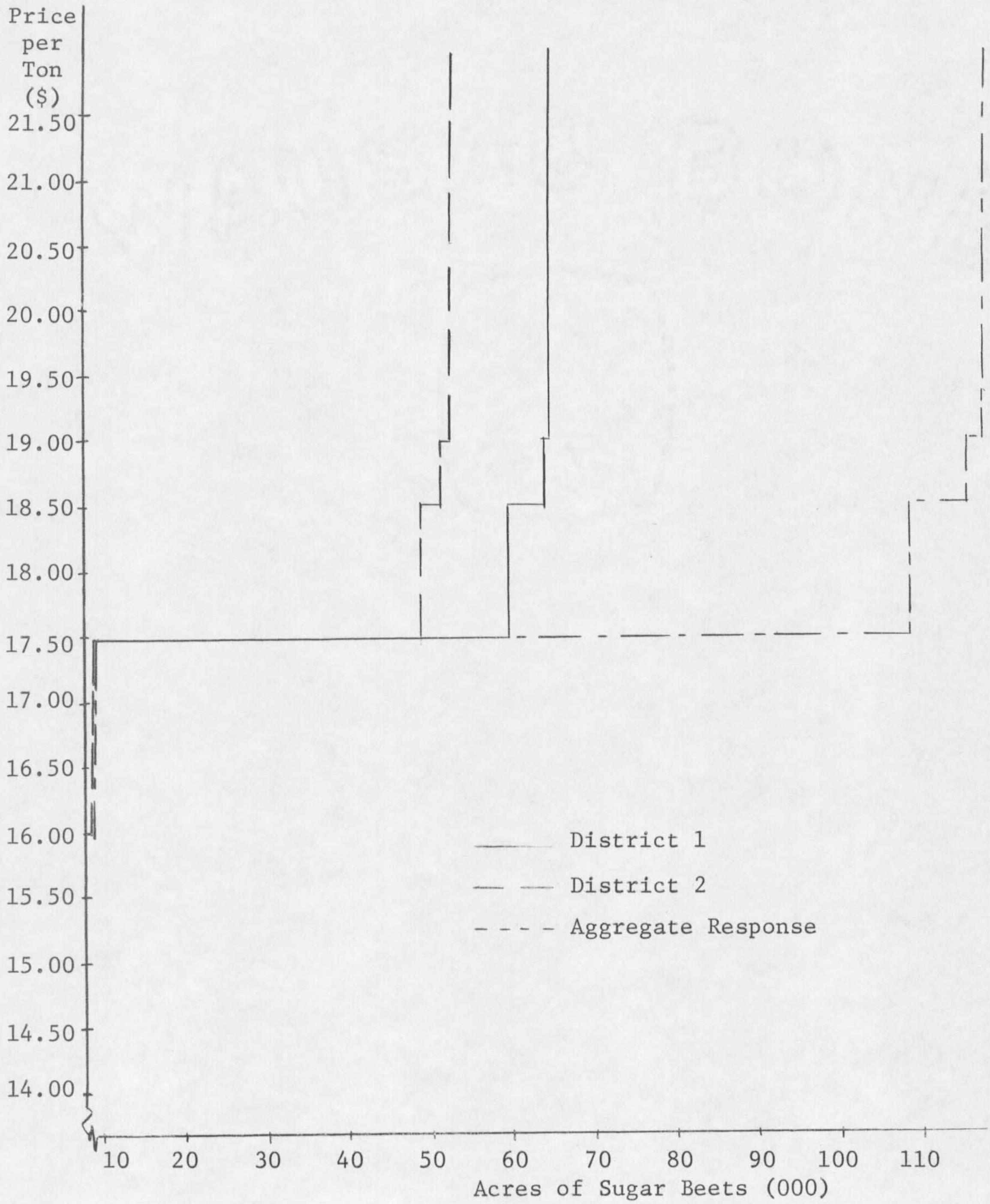

Figure 8. Sugar Beet Supply Response By District in 1980 for Regional Farm II.

30 percent of the irrigated land available in the region. This leaves 70 percent of the land for crops that would be used to break up disease and insect life cycles. District 1 farmers should plant 40,000 acres of beets using 31 percent of the available irrigated land while District 2 growers should plant 28.5 percent of the land or 30,478 acres of sugar beets at the equilibrium price in 1980.

TABLE XXVIII. SUGAR BEET SUPPLY RESPONSE BY DISTRICT IN 1980 FOR REGIONAL FARM II, INCLUDING LAND USE LIMITS.

Price Per Ton	Supply Response District 1	District 2	Totals
(Dollars)	(Acres)	(Acres)	(Acres)
14.00	35,441	23,813	59,254
14.50	36,576	27,430	64,006
15.00	38,293	27,430	65,723
15.50	38,294	29,054	67,348
16.00	38,294	29,054	67,348
16.50	38,294	30,154	68,448
17.00	39,266	30,154	69,420
17.50	40,741	30,478	71,219
18.00	40,741	30,478	71,219
18.50	41,364	32,775	74,139
19.00	41,364	32,775	74,139
19.50	41,364	33,676	75,040
20.00	42,012	33,832	75,844
20.50	42,126	34,637	76,763
21.00	42,126	34,637	76,763
21.50	42,126	34,637	76,763

Six cropping patterns are found in the profit maximizing linear program solutions with sugar beets priced at $17.50 per ton. These rotations are 2, 4, 5, 6, 9, and 14. Rotations 2, 5, and 6, are additions to the

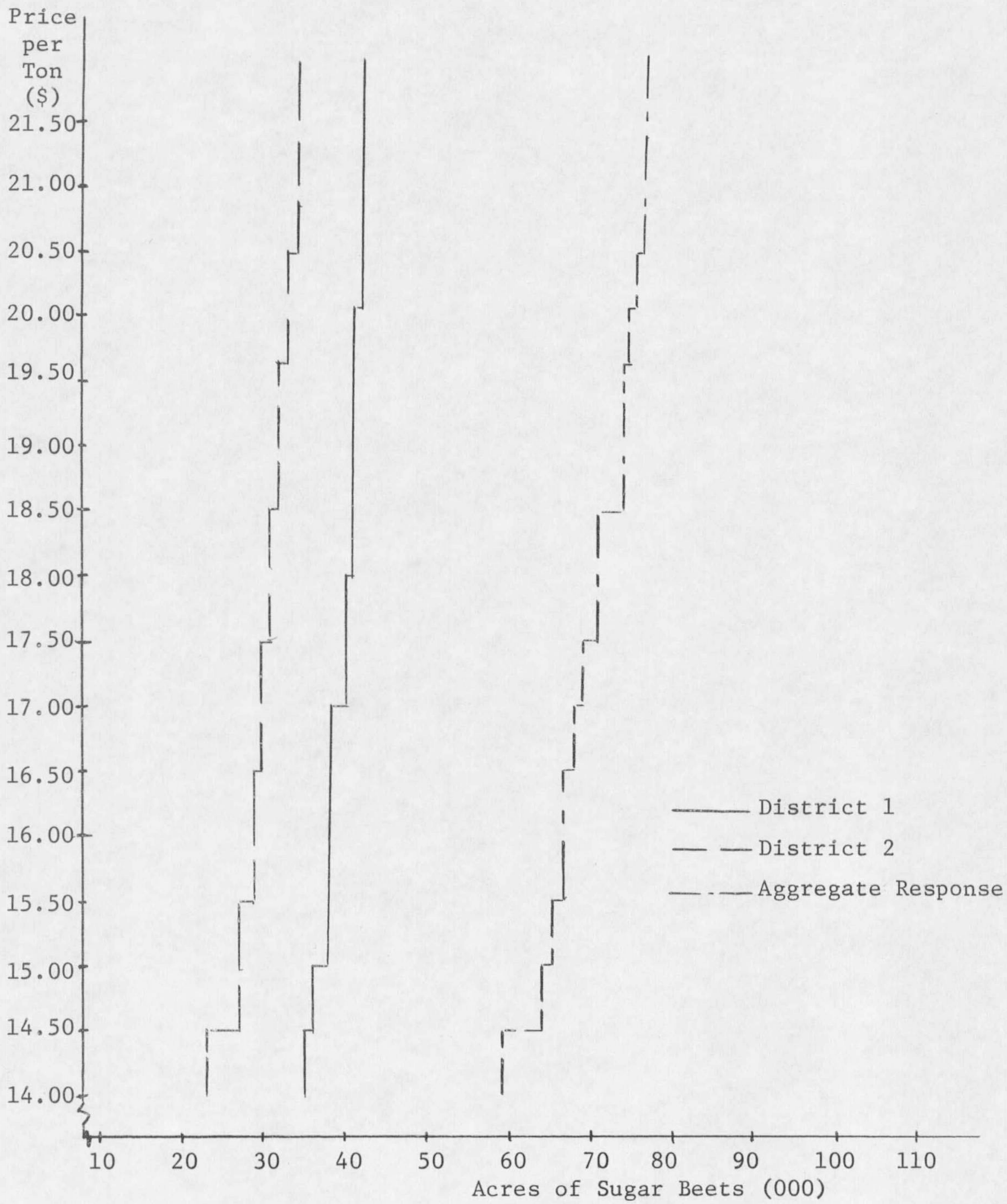

Figure 9. Sugar Beet Supply Response By District in 1980 for Regional Farm II, Including Land Use Limits.

optimal solution at $17.50 because of the upper limits placed on the cropping sequence activities. Rotations 2, 5, and 6, which contain sugar beets, replaced Rotation 9 when the latter reached the upper limit. In essense, Rotations 4, 5, and 6 represent the next best alternatives to Rotation 9.

It should be pointed out that the restricted supply estimate for sugar beets at $14.00 per ton was 59,254 acres. The regional response without upper bounds (Model I) no longer contained sugar beets at that price. This phenomenon is due to the upper limit rotation restriction on the various land types. In Model I, Rotation 9 entered the basis on the entire amount of land available. In Model II, Rotation 9 entered the solution only in the amount of the upper limit. Next "best" alternatives were then required to fill the remaining acreage.

Model III: An alternative 1980 sugar beet supply estimate was made using three typical farms as the responding units. The representative farms selected were based on three size classifications: 153, 263, and 635 irrigated acre units.

Each representative farm consisted of four land types similar to those defined for the regional model supply estimates. The number of acres of irrigated land of each type on the representative farms was based on the percentage of a given type of land in each district of the regional model; i.e., Land 1, District 1, represented 39.8 percent of all land available for crop production in District 1. This percentage coefficient was used to determine the number of acres of Land 1 on each of three representative farms (Table XXIX).

TABLE XXIX. THE NUMBER OF ACRES OF IRRIGATED LAND TYPES ON THREE TYPICAL FARMS, REGION II, 1980.

Land Types by District	Percent Land Type of Total Land	Typical Farm Size By Land Type (153 acres)	(263 acres)	(635 acres)
District 1				
Land 1	39.8	61	105	253
Land 2	46.0	70	121	292
Land 3	7.3	11	19	46
Land 4	6.9	11	18	44
District 2				
Land 1	57.0	87	150	362
Land 2	25.5	39	67	162
Land 3	5.3	8	14	34
Land 4	12.2	19	32	77

The number of units of family labor per typical farm was determined for the purpose of estimating the number of hours of family labor that would be available for crop production in 1980 (Table XXX).

TABLE XXX. HOURS OF FAMILY LABOR AVAILABLE ON TYPICAL FARMS, 1980.

Farm Size	Average Family Workers Per Farm	Number of Hours Available for Crop Production, 1980
153	1.70	3,009
263	1.58	2,797
635	1.94	3,434

The representative farm models were specified so that each farm had equal opportunity to select any one of a comination of crop rotations for the purpose of maximizing profits. The crop rotation activities are the same as those specified in the regional models. 1/ Furthermore, the regional farm net revenue coefficient for each rotation was used regardless of typical farm size specified. 2/

A sugar beet supply estimate was made for each typical farm in each of the two districts. The individual farm responses were expanded by the number of farms of that size group expected in 1980 (Table XXXI).

TABLE XXXI. THE NUMBER OF TYPICAL FARMS IN 1980, SOUTHEASTERN REGION.

Typical Farm Size	Percent of Sampled Farms 1966	Number of Farms Expected, 1980
153	.15	78
263	.53	274
635	.32	165

The expanded typical farm supply estimates of each district were summed to form the regional supply estimate for 1980 (Table XXXII and Figure 10). At $17.50, the 1980 projected price, 91,164 acres of sugar beets should be produced. Typical Farm 3 (635 acres) should produce 49,088 acres of beets while Farm 2 (263 acres) and Farm 1 (153 acres) should produce 36,031 and 6,045 acres of sugar beets respectively at $17.50 per ton.

1/ See page 96.

2/ See page 54.

TABLE XXXII. SUGAR BEET SUPPLY RESPONSE BY TYPICAL FARMS IN 1980 FOR REGION II.

Price Per Ton	Farm 1 (153 acres)	Farm 2 (263 acres)	Farm 3 (635 acres)	Totals
(Dollars)	(acres)	(acres)	(acres)	(acres)
14.00	624	0	0	624
14.50	624	0	0	624
15.00	2,769	3,425	5,033	11,227
15.50	3,908	3,425	5,033	12,366
16.00	3,908	16,303	23,760	43,971
16.50	5,655	33,702	44,055	83,412
17.00	6,045	36,031	44,055	86,131
17.50	6,045	36,031	49,088	91,164
18.00	6,045	36,031	49,088	91,164
18.50	6,045	36,031	52,305	91,164
19.00	6,045	36,031	52,305	91,164
19.50	6,045	36,031	52,305	91,164
20.00	6,045	36,031	52,305	91,164
20.50	6,045	36,031	52,305	91,164
21.00	6,045	36,031	52,305	91,164
21.50	6,045	36,031	52,305	91,164

Summary

Regional and typical farm sugar beet supply responses were made in this chapter. For the Southeastern Region the typical farm response is greater than the Regional Model II response but less than Regional Model I. At prices below $17.50 the response of Model I and III vary much more than the results of Model II. At the projected 1980 sugar beet price ($17.50) growers in the Southeastern Region should produce between 71,219 and 109,248 acres of sugar beets (Table XXXIII and Figure 11).

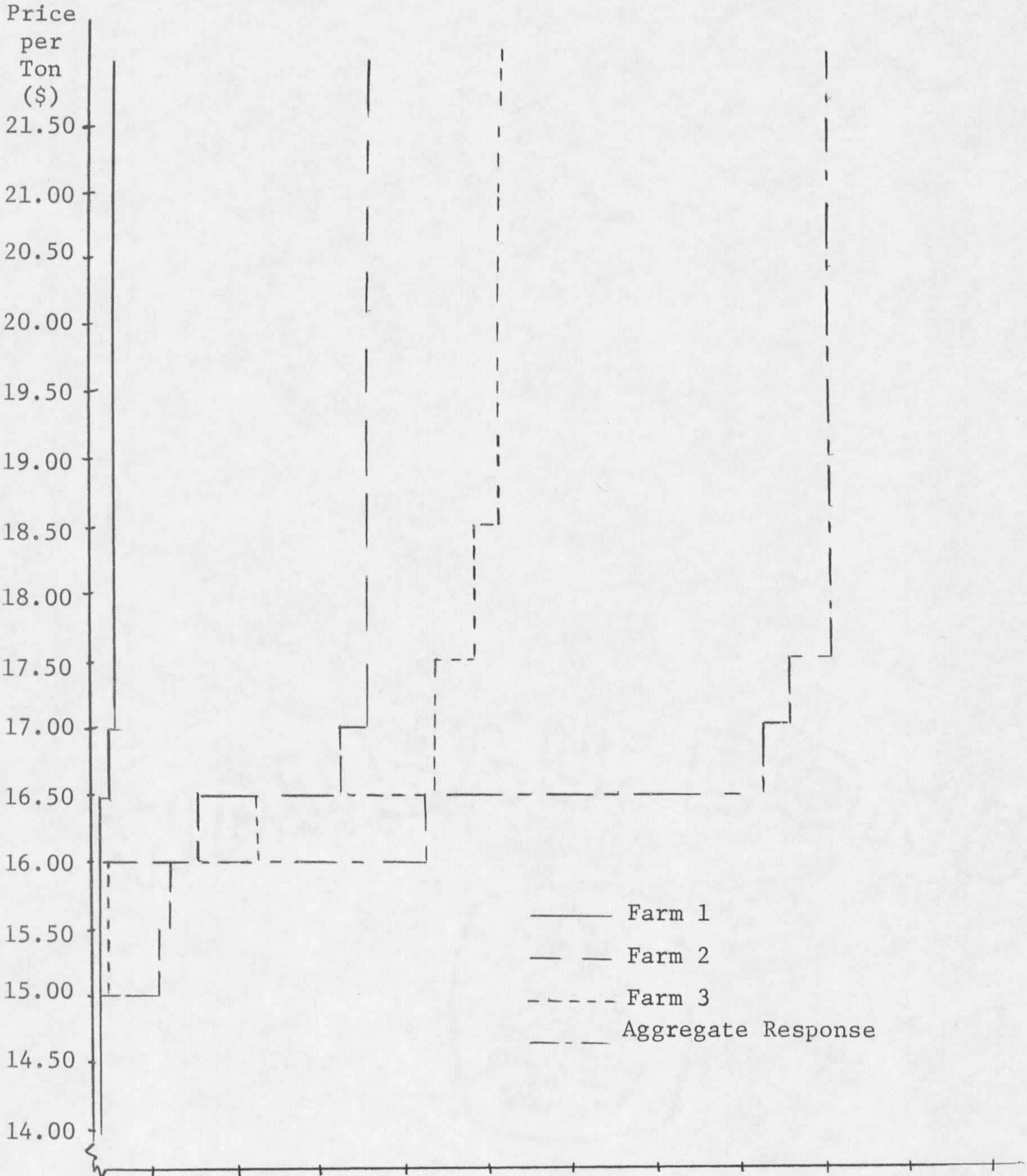

Figure 10. Sugar Beet Supply Response by Typical Farms in 1980 for Region II.

TABLE XXXIII. COMPARISON OF THREE ALTERNATIVE SUGAR BEET SUPPLY RESPONSES FOR THE SOUTHEASTERN REGION OF MONTANA, 1980.

Price Per Ton	Model I Region	Model II Region a/	Model III Typical Farms
(Dollars)	(acres)	(acres)	(acres)
14.00	0	59,254	624
14.50	0	64,006	624
15.00	0	65,723	11,227
15.50	0	67,348	12,366
16.00	8,828	67,348	43,971
16.50	8,828	68,448	83,412
17.00	8,828	69,420	86,131
17.50	109,248	71,219	91,164
18.00	109,248	71,219	91,164
18.50	116,869	74,139	91,164
19.00	118,759	74,139	91,164
19.50	118,759	75,040	91,164
20.00	118,759	75,844	91,164
20.50	118,759	76,763	91,164
21.00	118,759	76,763	91,164
21.50	118,759	76,763	91,164

a/ Includes land use limits.

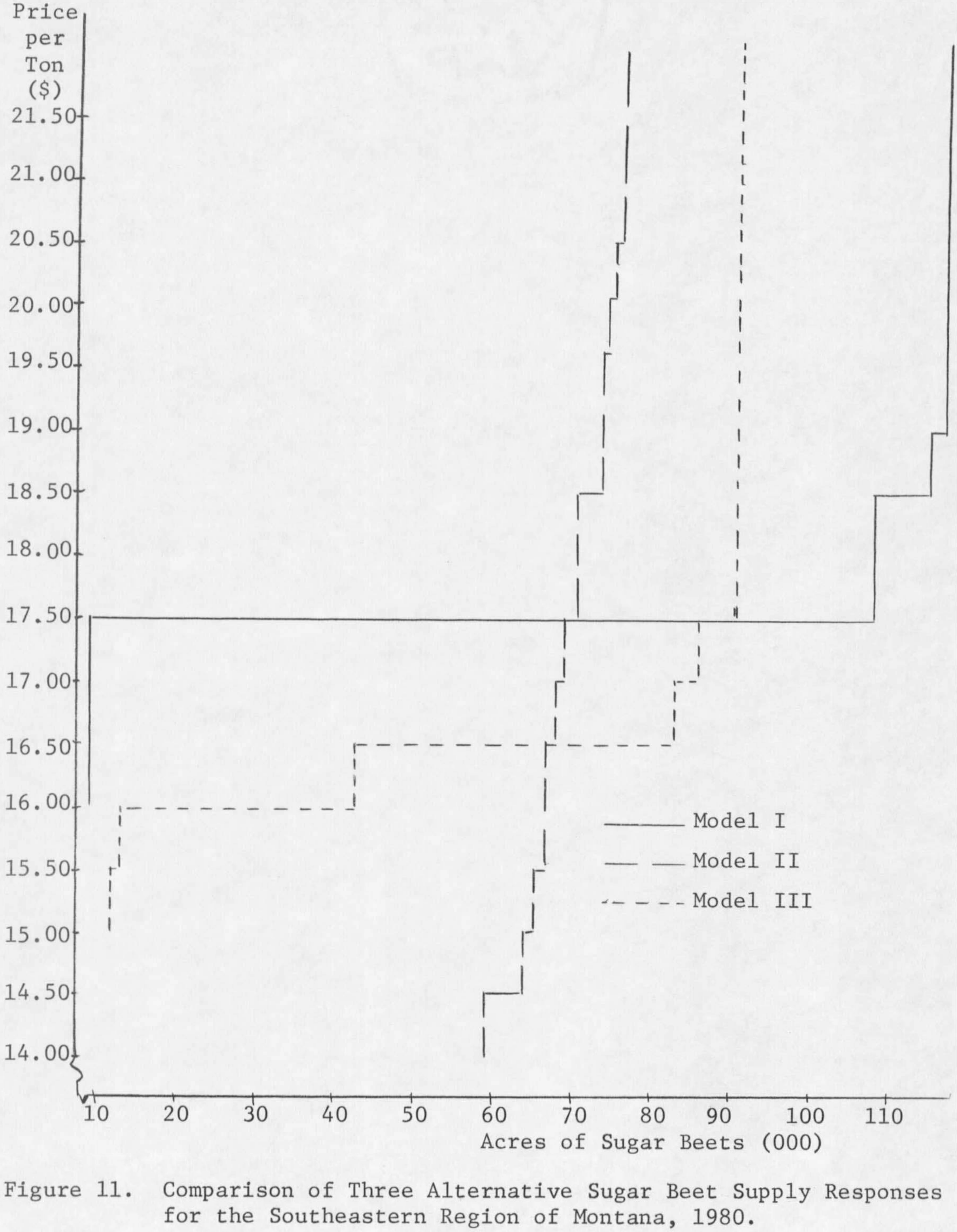

Figure 11. Comparison of Three Alternative Sugar Beet Supply Responses for the Southeastern Region of Montana, 1980.

CHAPTER VI

SUGAR BEET PRODUCTION RESPONSE: NORTH AND WEST CENTRAL REGION

A long run sugar beet supply estimate for the north and west central regions has been made. This chapter describes the area under study and the supply estimates for the regional and typical farms.

Area Under Study

The north and west central regional farm is made up of two areas. The west central area includes the irrigated lands of four counties: (1) Stillwater, (2) Carbon, (3) Yellowstone, and (4) the western part of Treasure. The north central area includes Blaine and Phillips counties.

Regional Farm III is divided into three districts: District 1, including the irrigated lands northeast of Billings, Montana, adjacent to the Yellowstone River northeast to Hysham in Treasure County and District 2, consisting of potential sugar beet production areas west and southwest of Billings in Stillwater, Carbon, and Yellowstone counties. The third district is in the northern part of the state in Blaine and Phillips counties (Figure 12).

Regional Farm III includes the major portion of the Great Western Sugar Company factory district with refining facilities located at Billings.

Water

The primary source of water in District 1 (area northeast of Billings) is the Yellowstone River, which supplies a number of private ditch companies

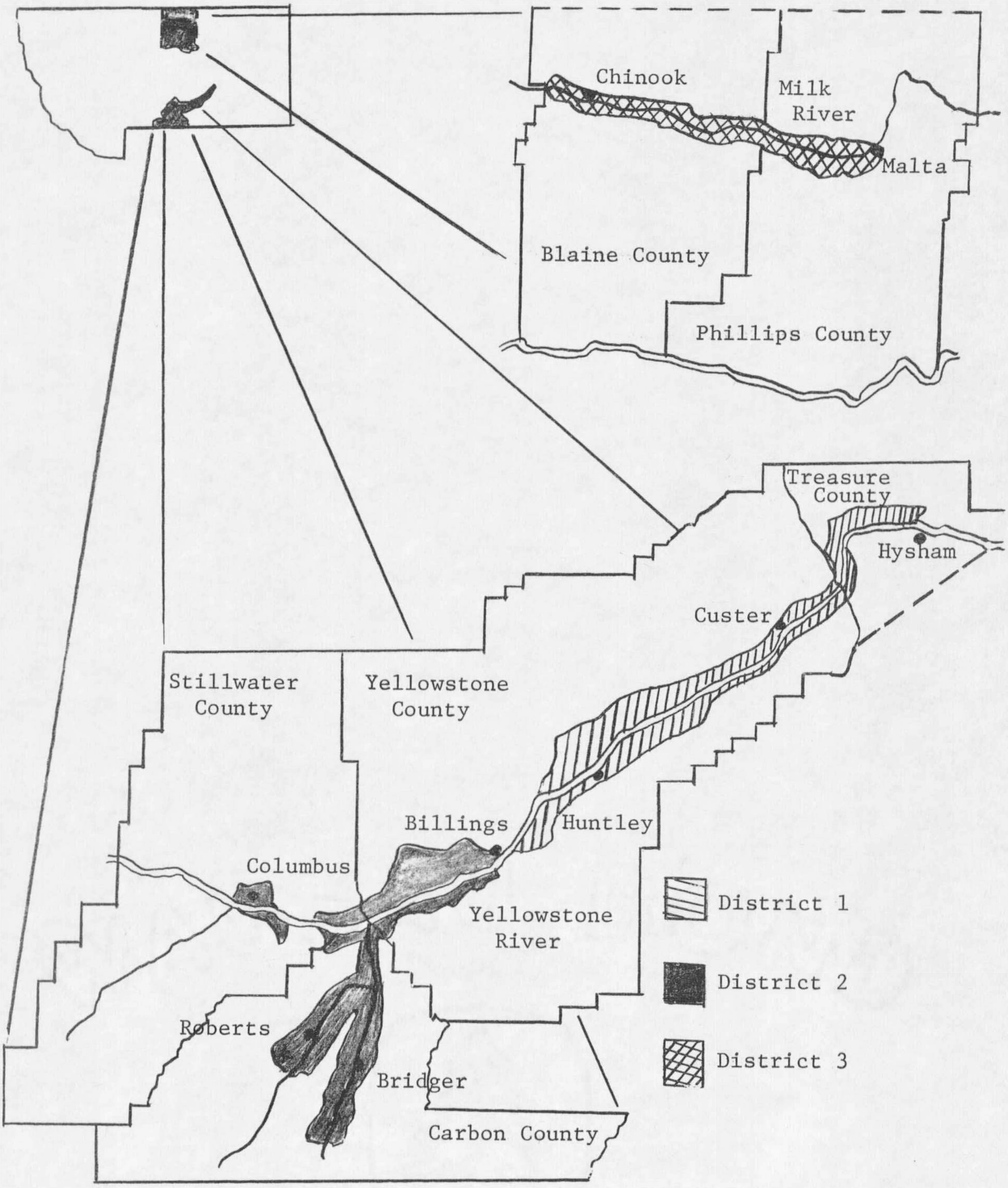

Figure 12. Regional Farm III--North and West Central Montana--By District.

and the Bureau of Reclamation Project at Huntley. The Yellowstone, Clark Fork, and Stillwater Rivers are the primary sources of water in District 2.

The northern area (District 3) is located in the Milk River Basin. Farmers in the area depend upon the Milk River and some ground water pumping units for irrigation water.

Climate

The climate of Regional Farm III is similar to the other Great Plains regions previously discussed. Generally, hot summers, cold winters, low rainfall, long sunny days, and low relative humidity characterize the region's climate. The normal long range annual precipitation for District 1 and 2 is 12.65 inches with 9.20 inches occurring in the growing season. District 3 receives 12.52 inches of precipitation annually with 9.25 inches falling during the growing season (Table XXXIV).

The average length of the growing season in the region is near 120 days. However, the growing season of District 2 often times is below 90 days. In the last 20 years the lowest number of days in the growing season reported at Chinook (District 3) was 85 days.

Temperatures in the region vary by district. The northern district varies from 110 degrees Fahrenheit to 60 degrees below zero with the mean growing season temperature near 66 degrees Fahrenheit. 1/ The

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1/ Soil Survey of the Milk River Area, Montana, U.S.D.A., Series 1928, No. 22, pp. 5-6.

southern districts of Regional Farm III are affected by the mountain ranges that lie to the west of the area. Temperatures vary from 110 degrees to 50 degrees below zero, with the average growing season temperatures near 75 degrees. The southern area is susceptible to warm winds in the winter. Summer winds do not generally hamper cropping operations in the irrigated areas of Regional Farm III.

TABLE XXXIV. CLIMATE DATA, REGIONAL FARM III. a/

District	Annual Normal Precipitation	Growing Season Precipitation	Average Number of Days Between Freezing Temperatures b/
	(Inches)	(Inches)	
1	12.03	8.88	121
2	13.26	9.51	111
3	12.52	9.25	119

a/ Source: Montana Agricultural Statistics, Montana Department of Agriculture, SRS, Helena, Montana.

b/ 32 degrees Fahrenheit.

Soils

Data concerning soil associations and series is available for most of the Regional Farm III area. Soils data for Carbon County is not available. In Districts 1 and 2 (Yellowstone County), 14 soil associations have been identified including 55 soil series. McRae-Lohmiller-Keiser Association makes up 7 percent of all the land surveyed in Yellowstone

County. This soil association is found on gently sloping Yellowstone Valley terraces. These soils are easily managed and are capable of high crop yields.

Other soils in the irrigated areas are Vananda and Arvada series which are well drained and olive gray in color. The Bew-Allentine soils of the terraces and fans are also considered highly productive soils. Havre and Glendive soils are found mostly in the lower terraces and flood plains of the Yellowstone Valley floor. Some of the Glendive soils are not well drained and, therefore, are not generally used for crop production. Havre soils usually support sugar beet and bean crops in the region. 2/

Because the soil associations identified in Yellowstone County lie near the Yellowstone River, it is reasonable to expect that similar soil series are found near the Yellowstone River in Carbon and Stillwater Counties (District 2).

The soils of District 3 best adapted for irrigated crops are Havre, Harlem, and Bowdoin. A wide range of soil types make up these series from fine sandy loam to clay. The Havre soil series constitutes 18 percent of all soils surveyed in the Milk River Basin while Harlem and Bowdoin represent 10.4 and 17 percent, respectively. 3/ Some Bowdoin is heavy clay, not adapted to irrigated crops.

2/ "Soil Survey Yellowstone County, Montana", unpublished report provided by the U.S.D.A., S.C.S, Bozeman, Montana, pp. 9-38.

3/ Soil Survey - Milk River, op. cit., pp. 12-30.

Crops and Yields

The crops grown on irrigated land within the bounds of Regional Farm III are sugar beets, alfalfa, dry beans, corn silage, oats, wheat, barley, dry peas, and potatoes. All interviewed growers reported sugar beet production and 84 percent raised alfalfa (Table XXXV).

TABLE XXXV. THE NUMBER OF FARMERS GROWING SPECIFIED IRRIGATED CROPS IN REGIONAL FARM III, 1966.

Irrigated Crop	Number of Farmers Growing Crops (38 Farmers)	Percentage of Farmers Interviewed Growing Specified Crops
Sugar beets	38	100.0
Alfalfa	32	84.2
Pasture	26	68.4
Barley	24	63.1
Corn silage	20	52.6
Wheat	19	50.0
Dry beans	16	42.1
Oats	10	26.3
Other hay	4	10.5
Peas	3	7.8
Potatoes	1	2.6
Clover seed	1	2.6
Green beans	1	2.6
Squash	1	2.6

The 1966 average yield for selected irrigated crops in Regional Farm III are reported in Table XXXVI.

Growers in Regional Farm III reported using crop rotations in order to maintain soil fertility and high crop yields. Fifteen rotational patterns were suggested by the farmers in the region. There were four crop rotations reported by 47 percent of the growers in the region. Five farmers did not use a set cropping pattern (Table XXXVII).

TABLE XXXVI. YIELDS FOR SELECTED CROPS, 1966 AND FIVE YEAR (1961-1966), WEIGHTED AVERAGES - REGIONAL FARM III.

Crop	Yield per Acre 1966	Yield per Acre 1961-1966
Sugar beets	17.07 tons	16.12 tons
Alfalfa	3.89 tons	3.94 tons
Barley	59.80 bushels	62.60 bushels
Corn Silage	19.61 tons	20.26 tons
Wheat	36.90 bushels	45.30 bushels
Dry beans	18.89 cwt.	20.35 cwt.
Oats	77.50 bushels	75.40 bushels
Other hay	3.25 tons	3.25 tons
Peas	33.20 cwt.	33.20 cwt.
Potatoes	300.00 cwt.	250.00 cwt.

The majority of the farmers in the southern two districts of the region reported that their cropping patterns were used in part to produce livestock from corn silage, alfalfa, barley, and sugar beet tops. In the northern district cattle feeding was not as popular, primarily because fed cattle markets are too far from the area.

Livestock

Billings represents a major livestock market in Montana. The majority of farmers in Districts 1 and 2 of the region reported cow-calf and livestock feeding enterprises. The survey in District 3 indicated a wide assortment of relatively small livestock operations. Many growers reported multiple livestock enterprises (Table XXXVIII).

TABLE XXXVII. REPORTED CROPPING PATTERNS USED BY GROWERS - REGIONAL FARM III, 1966.

Crop Sequence	Number of Growers Using Crop Sequence
Grain, 3 alfalfa, grain, beets, beets, beets	6
Grain, 4 alfalfa, beans, beets, grain, beets	5
Grain, 4 alfalfa, corn sil, beets, grain, beets	4
Grain, 3 alfalfa, corn sil, beets,	3
Grain, 4 alfalfa, grain, beets,	2
Grain, 5 alfalfa, corn sil, beets,	2
Beets, corn sil, corn sil,	2
Grain, 3 alfalfa, beans, beans, beans, beets, beets	2
Beets, corn sil, grain,	2
Grain, beets, grain, beets,	1
2 alfalfa, potatoes, beets, beets, potatoes	1
Beets, corn sil, beans,	1
Corn sil, peas, beets,	1
Grain, 3 alfalfa, beets, beets, beets, beets	1
No rotation pattern reported	5

Labor

The family farm unit is the primary source of labor in Regional Farm III. Other labor is hired depending upon the reason of the year, the type of cropping patterns followed and the size of the family labor force.

It has been determined that an average of 1.375 workers per family farm were employed in 1966. Some full time labor was reported to supplement family labor. During the summer, high school boys fill worker demands on irrigated farms.

TABLE XXXVIII. LIVESTOCK ENTERPRISES REPORTED BY FARMERS - REGIONAL FARM III, 1966.

Livestock Organization	Number of Farmers Reporting		Percentage of Farmers Reporting	
Beef feeding		24		63.1
Lamb feeding		4		10.5
Swine feeding		1		2.6
Steers on winter stubble		3		7.8
Beef cows for calves		27		71.0
less than 10 head	3		7.8	
more than 10, less than 20	5		13.1	
more than 20, less than 30	7		18.4	
more than 30	12		31.5	
Dairy cows for milk		7		18.4
less than 10 head	4		10.5	
more than 10, less than 20	3		7.8	
Ewes and rams		3		7.8
Poultry		6		15.7
Hogs		8		21.0

Sugar Beet Supply Model: Regional Farm III

The linear programming model constructed to represent Regional Farm III is made up of cropping pattern activities, restrictions that limit sugar beet production, and appropriate input-output coefficients. The model was specified with 1980 price and resource projections.

Fourteen crop rotations were specified in the objective function of the Regional Farm III linear programming model (Table XXXIX). The cropping patterns were reported by 38 growers of the region, and by the Montana State Experimental Station at Huntley. 4/

4/ Larson, et. al., Irrigated Crop Rotation, op. cit.

TABLE XXXIX. CROP ROTATION ALTERNATIVES OF REGIONAL FARM III, 1980.

Rotation Number	Cropping Sequence	Number of Years
1	Oats , 3 alfalfa, wheat , beets , beets , beets	8
2	Barley, 4 alfalfa, beans , beets , wheat , beets	9
3	Barley, 4 alfalfa, corn sil, beets , wheat , beets	9
4	Oats , 3 alfalfa, corn sil, beets	6
5	Oats , 3 alfalfa, beans , beans , beets , beets	8
6	Beets , corn sil , corn sil	3
7	Oats , 3 alfalfa, potatoes, beets	6
8	Oats , 3 alfalfa, beans , corn sil, corn sil	7
9	Oats , corn sil , beans	3
10	Barley, 3 alfalfa, beans , beans	6
11	Barley, 4 alfalfa, beans , wheat , beans	8
12	Barley, 3 alfalfa, corn sil, corn sil, corn sil	7
13	Oats , 3 alfalfa, potatoes, beans	6
14	Barley, 3 alfalfa, corn sil, potatoes,	6

Net revenue coefficients indicating the profitableness of the cropping sequence reflect 1980 costs, returns, and yields. 5/ Each net revenue coefficient reflected the cost of water within a given district, as well as appropriate crop yields for given land type within the districts. Each rotation can be produced on each land type in each district. In some cases, however, cropping sequences that include sugar beets are restricted to Land Types 1 through 3. Usually, Land Type 4 is not of the quality to produce sugar beets. 6/

5/ See p. 56 , for the method of forecasting cost and returns.

6/ Land 4 in some districts is capable of supporting sugar beets. The Soil Conservation Service has identified the areas where Land 4 can support sugar beets.

Regional Farm III contained 310,708 irrigated acres of land in 1966. An additional 45,290 irrigated acres of land can be expected to be available for production in 1980 due to the development of new irrigation units. New state irrigation projects are expected to add another 40,100 irrigated acres to production, while the Bureau of Reclamation projects will add 5,190 acres 7/ (Table XL).

TABLE XL. INVENTORY OF LAND IN REGIONAL FARM III, BY DISTRICT, LAND CLASS, AND NEW IRRIGATION PROJECTS, 1980.

District	Class 1	Class 2	Class 3 (Acres)	Class 4	Totals
District 1					
1966 inventory	32,322	46,605	4,826	13,041	96,794
a/ State projects 1980	4,275	6,157	640	1,728	12,800
a/ Bur. of Reclam. 1980	1,503	2,164	225	608	4,500
Subtotal	38,100	54,926	5,691	15,377	114,094
District 2					
1966 inventory	58,537	38,284	19,476	8,430	124,727
a/ State projects 1980	657	430	218	95	1,400
a/ Bur. of Reclam. 1980	------	------	------	-----	-------
Subtotal	59,194	38,714	19,694	8,525	126,127
District 3					
1966 inventory	39,805	40,911	4,740	3,731	89,187
a/ State projects 1980	11,551	11,888	1,373	1,088	25,900
a/ Bur. of Reclam. 1980	223	230	27	210	690
Subtotal	51,579	53,029	6,140	5,029	115,777
Totals	148,873	146,669	31,525	28,931	355,998

a/ State and Bureau of Reclamation projects that will be completed by 1980.

7/ State Water Conservation Board, Preliminary Report, Water Needs of Montana, February 1962 and personal correspondence from B. E. Garlinghouse, Chief, Irrigation Division, Bureau of Reclamation, Region 6, United States Department of the Interior, Great Falls, Montana, June 26, 1968.

Supply Response:

Three models were developed for the purpose of estimating sugar beet production: (1) regional farm response, (2) regional farm response with specific land use restrictions, and (3) representative farm response. Model 1: The 1980 estimated sugar beet supply response for the west and north central regional farm in Montana at $17.50 per ton is 62,233 acres or 17.5 percent of the available land (Table XLI and Figure 13). The sugar beet supply response in District 1 (area northeast of Billings) was 20,552; Districts 2 and 3 (west of Billings and the High Line) are expected to produce 21,873 and 19,808 acres of sugar beets respectively at the equilibrium price.

TABLE XLI. SUGAR BEET SUPPLY RESPONSE BY DISTRICT IN 1980, FOR REGIONAL FARM III.

Price per Ton	Supply Response			
	District 1	District 2	District 3	Totals
	(acres)	(acres)	(acres)	(acres)
14.00	9,154	13,783	9,861	32,798
14.50	9,154	16,318	14,625	40,097
15.00	16,452	19,600	18,457	54,509
15.50	19,527	21,305	19,483	60,315
16.00	19,527	21,305	19,483	60,315
16.50	20,552	21,873	19,808	62,233
17.00	20,552	21,873	19,808	62,233
17.50	20,552	21,873	19,808	62,233
18.00	20,552	21,873	19,808	62,233
18.50	26,902	31,738	28,405	87,045
19.00	36,057	38,191	37,243	111,491
19.50	36,057	38,191	37,243	111,491
20.00	36,057	38,191	37,243	111,491
20.50	37,006	41,474	38,267	116,747
21.00	38,288	42,185	38,674	119,147
21.50	38,288	42,185	38,674	119,147

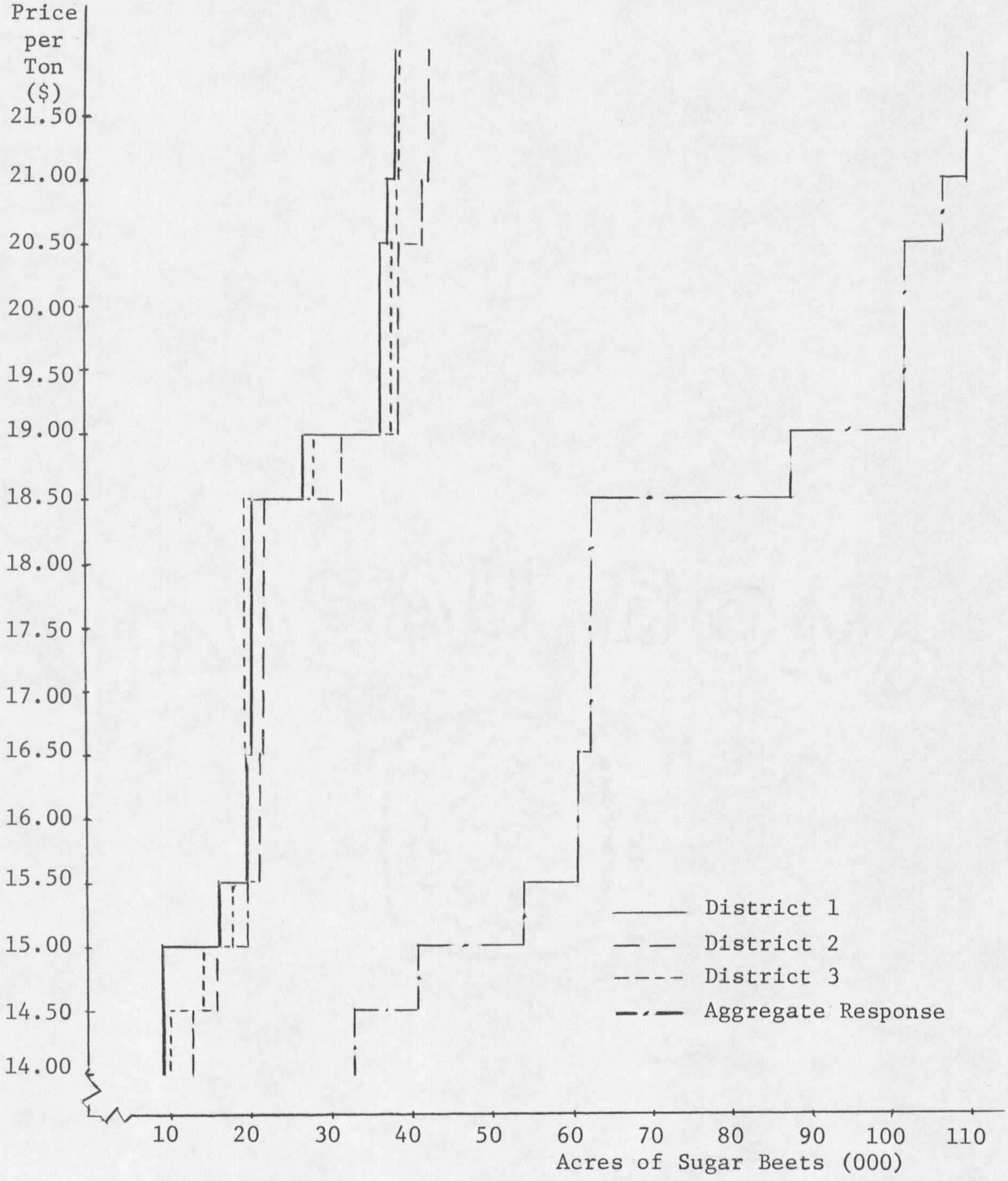

Figure 13. Sugar Beet Supply Response by District in 1980 for Regional Farm III.

The rotations in the optimal solution were 6, 7, and 14. Rotation 7 dominated Land Types 1 - 3 in all districts. Rotation 7 consists of oats, alfalfa, potatoes, and sugar beets. Rotations 6 and 14 were in the solution on Land Type 4.

At prices below equilibrium, the same rotations were in the solutions, however, Rotation 14 was found on Land Type 1 and 2. As the price of sugar beets were revised upward; Rotation 7, containing sugar beets and potatoes, replaced Rotation 14, consisting of potatoes and grain. At \$21.50 per ton all rotations in the solutions consisted in part of sugar beets; Rotation 1 on Land 4; Rotation 6 on all other Lands. Rotation 6 replaced Rotation 7 on all land types at a price of \$21.50 per ton.

Model II: The regional farm sugar beet rotations were further restricted by including a land use limitation in the model. The rotations specified in the objective function were not allowed to use more than one-fifth of the available irrigated land. The land use restriction was placed for the purpose of reflecting management practices that should take place on irrigated farms in order to avoid disease and nematode problems. The estimated sugar beet supply response for 1980 under the land use limitation is shown in Table XLII and Figure 14.

At \$17.50 per ton, the 1980 projected sugar beet price, 47,215 acres of beets should be planted. This estimate is 15,018 acres less than the Model I estimate.

TABLE XLII. SUGAR BEET SUPPLY RESPONSE BY DISTRICT IN 1980 FOR REGIONAL FARM III, INCLUDING LAND USE LIMITS.

Price per Ton	Supply Response			
	District 1	District 2	District 3	Totals
(Dollars)	(acres)	(acres)	(acres)	(acres)
14.00	11,871	15,766	14,469	42,106
14.50	14,252	15,766	14,470	44,488
15.00	14,252	15,766	14,470	44,488
15.50	14,261	15,766	14,470	44,497
16.00	14,264	15,768	14,473	44,505
16.50	14,264	15,768	14,473	44,505
17.00	15,705	16,566	14,944	47,215
17.50	15,705	16,566	14,944	47,215
18.00	15,705	21,714	14,944	52,363
18.50	15,705	21,716	14,944	52,365
19.00	19,272	25,747	24,748	68,946
19.50	19,805	27,592	25,324	72,721
20.00	24,562	27,592	25,327	77,481
20.50	24,562	27,592	25,327	77,481
21.00	24,562	27,592	25,327	77,481
21.50	25,416	28,062	25,607	79,089

The crop rotations in the profit maximizing solution at $17.50 per ton of beets are 1, 3, 6, 7, 13, and 14. Rotations 6, 7, 13, and 14 were in the optimum solution in the amount specified for the land use restriction. 8/

Model III: An alternative way of estimating the number of acres of sugar beets that would be grown under alternative beet prices, is by using a typical farm as the responding unit. Three representative farms were

8/ Refer to p. 119.

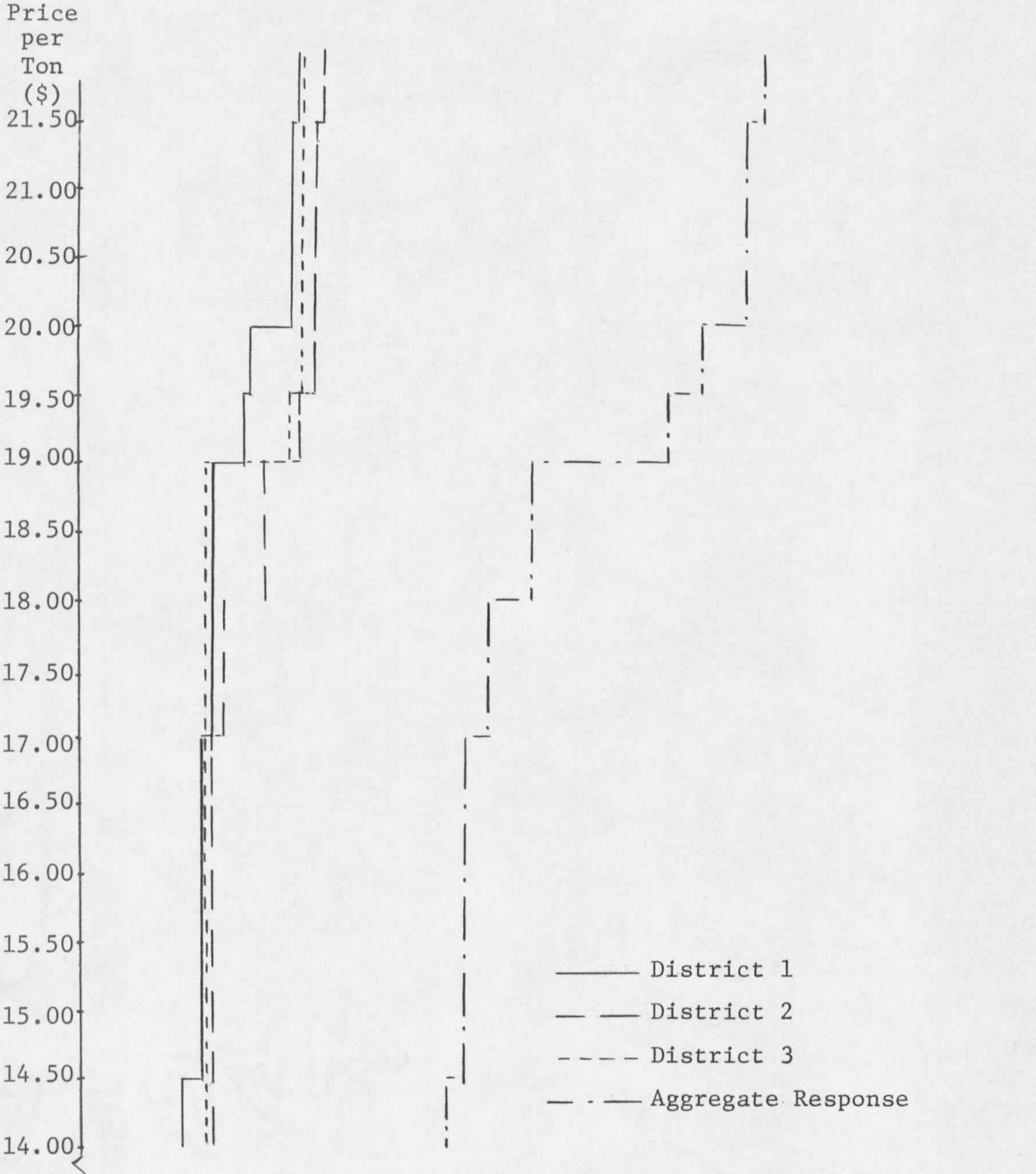

Figure 14. Sugar Beet Supply Response by District in 1980 for Regional Farm III, Including Land Use Limits.

defined typifying three size groups found in the north and west central region: 176, 227, and 405 acre units.

Each representative farm model was specified with rotation activities, sugar beet resource restrictions, and input-output coefficients. The crop rotation activities are the same as the regional farm model specifications. The net revenue coefficients associated with the regional farm sequence activities were used in the representative farm model for all three farm sizes.

The resources that restrict sugar beet production are land and family labor. Each typical farm was specified with four types of land in quantities that reflect the percentage of land types in the regional farm model (Table XLIII).

The number of family labor hours available for crop production during 177 days at 10 hours per day was determined for each typical farm. The number of family workers per farm were ascertained from a survey of growers in the region. The number of hours available for crop production have been estimated (Table XLIV).

Based on the specified typical farm models, a sugar beet supply response was projected for the region in 1980. The individual farm responses were expanded by the number of farms expected to exist in 1980 (Table XLV).

The expanded typical farm sugar beet supply responses were horizontally summed to form a 1980 regional supply response for sugar beets (Table XLVI and Figure 15).

TABLE XLIII. THE NUMBER OF ACRES OF IRRIGATED LAND TYPES ON THREE TYPICAL FARMS, REGION III, 1980.

Land Types By District	Percent of Land Type of Total Land	Typical Farm Size by Land Type		
		176 acres	227 acres	405 acres
District 1				
Land 1	33.4	59	76	135
Land 2	48.1	84	109	195
Land 3	5.0	9	11	20
Land 4	13.5	24	31	55
District 2				
Land 1	46.9	83	107	190
Land 2	30.7	54	70	124
Land 3	15.6	27	35	63
Land 4	6.8	12	15	28
District 3				
Land 1	44.6	78	101	181
Land 2	45.8	81	104	186
Land 3	5.3	9	12	21
Land 4	4.3	8	10	17

TABLE XLIV. HOURS OF FAMILY LABOR AVAILABLE ON TYPICAL FARMS, 1980.

Farm Size	Family Workers per Farm	Number of Hours Available for Crop Production 1980
176	1.36	2,407
227	1.69	2,991
405	2.60	4,602

TABLE XLV. THE NUMBER OF TYPICAL FARMS IN 1980, NORTH AND WEST CENTRAL REGION.

Typical Farm Size	Percent of Sampled Farms, 1966	Number of Farms Expected, 1980
176	21.8	342
227	28.1	441
405	50.1	787

TABLE XLVI. SUGAR BEET SUPPLY RESPONSE BY TYPICAL FARMS IN 1980 FOR REGION III.

Price per Ton	Farm 1 (176 acres)	Farm 2 (227 acres)	Farm 3 (405 acres)	Totals
(Dollars)	(acres)	(acres)	(acres)	(acres)
14.00	4,218	15,435	22,036	41,689
14.50	9,348	18,081	48,532	75,961
15.00	11,058	18,081	57,189	86,328
15.50	11,058	18,081	57,189	86,328
16.00	11,058	18,081	57,189	86,328
16.50	11,058	18,081	57,189	86,328
17.00	11,058	18,081	57,189	86,328
17.50	11,058	18,081	57,189	86,328
18.00	11,058	24,843	57,189	93,090
18.50	15,276	24,843	79,225	119,344
19.00	19,380	31,752	101,260	152,392
19.50	19,380	31,752	101,260	152,392
20.00	19,380	31,732	101,260	152,392
20.50	20,178	33,222	105,983	159,383
21.00	20,178	33,222	105,983	159,383
21.50	20,178	33,222	105,983	159,383

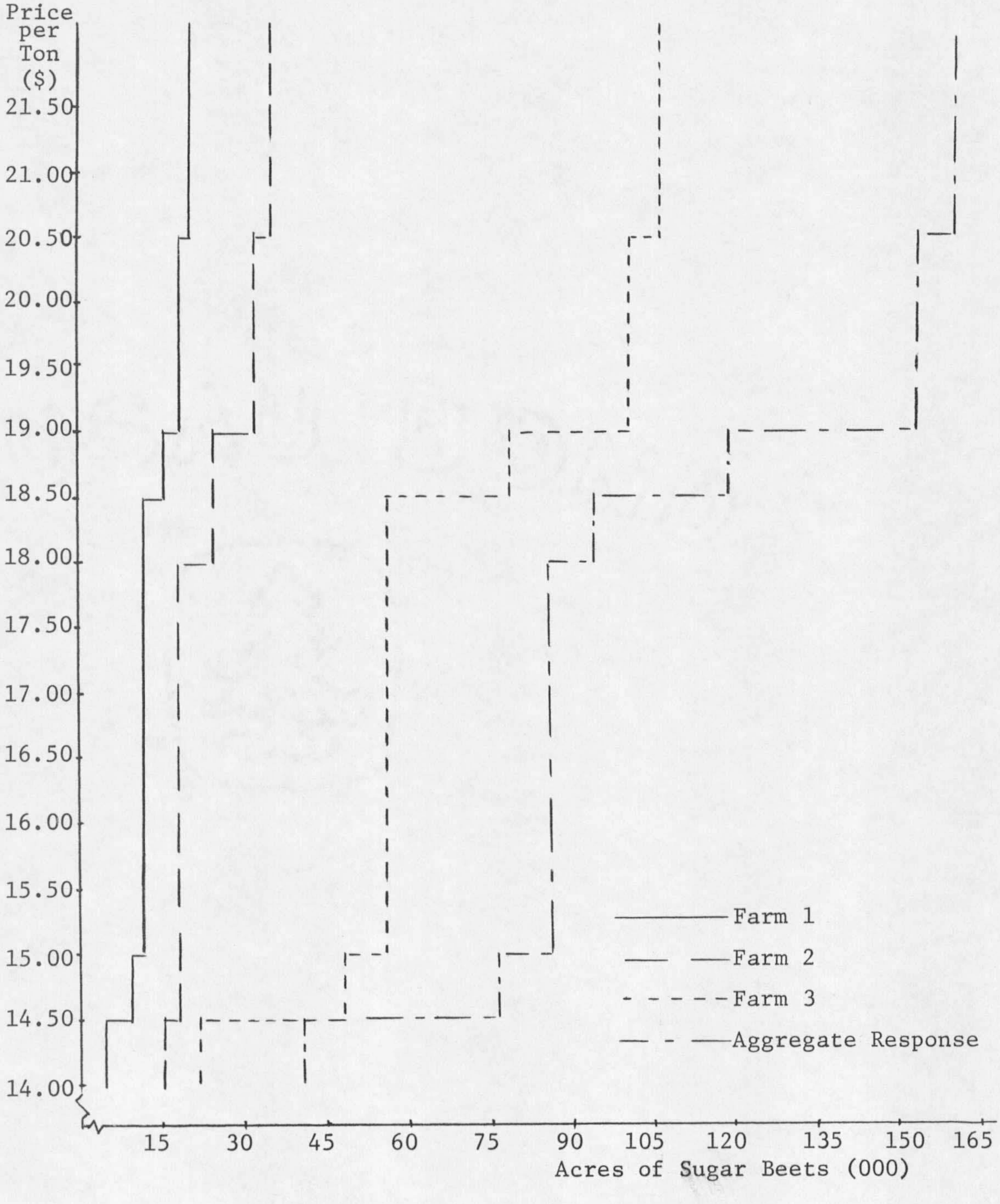

Figure 15. Sugar Beet Supply Response By Typical Farms in 1980 for Region III.

The results of the analysis show that 86,328 acres of sugar beets should be production at $17.50 per ton. The largest typical farms (405 acres) should produce 57,189 acres of beets at $17.50 per ton. Farm 2 (227 acres) and Farm 1 (176 acres) should grow 18,081 and 11,058 acres of sugar beets respectively.

Summary

Three sugar beet supply response models including regional and typical farm analysis were made in this chapter. At beet prices above $14.50 the typical farm model supply estimate is greater than either regional model responses. Model II resulted in the lowest estimate of sugar beet production. One should expect between 47,215 and 93,090 acres of sugar beets in the north and west central regions in 1980 at $17.50 per ton (Table XLVII and Figure 16).

TABLE XLVII. COMPARISON OF THREE ALTERNATIVE SUGAR BEET SUPPLY RESPONSES FOR THE NORTH AND WEST CENTRAL REGIONS OF MONTANA, 1980.

Price per Ton	Model I Region	Model II Region a/	Model III Typical Farm
(Dollars)	(Acres)	(Acres)	(Acres)
14.00	32,798	42,106	41,689
14.50	40,097	44,488	75,961
15.00	54,509	44,488	86,328
15.50	60,315	44,497	86,328
16.00	60,315	44,505	86,328
16.50	62,233	44,505	86,328
17.00	62,233	47,215	86,328
17.50	62,233	47,215	86,328
18.00	62,233	52,363	93,090
18.50	87,045	52,365	119,344
19.00	111,491	68,946	152,392
19.50	111,491	72,721	152,392
20.00	111,491	77,481	152,392
20.50	116,747	77,481	159,383
21.00	119,147	77,481	159,383
21.50	119,147	79,089	159,383

a/ Includes land use limits.

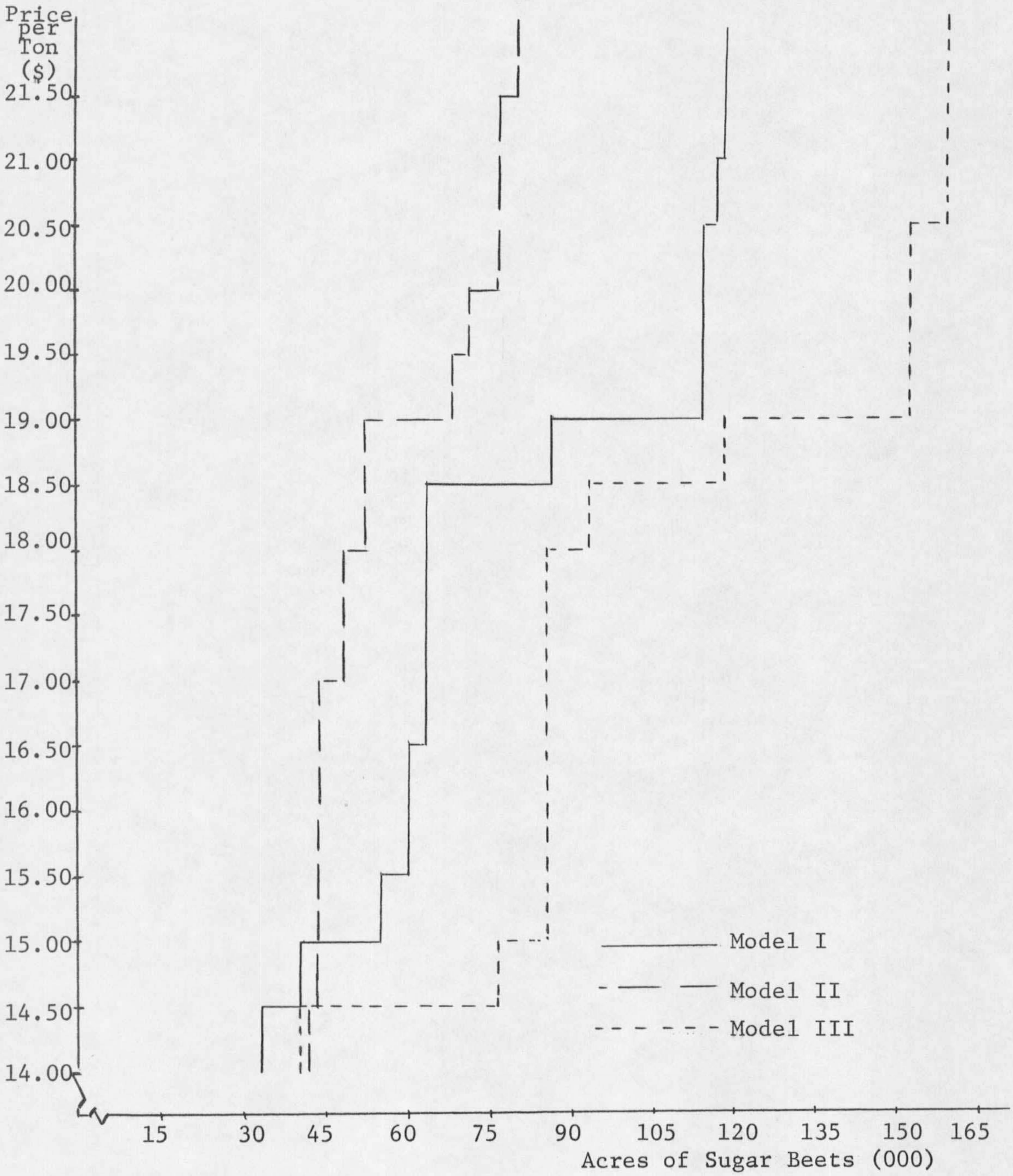

Figure 16. Comparison of Three Alternative Sugar Beet Supply Responses for the North and West Central Regions of Montana, 1980.

CHAPTER VII

SUGAR BEET PRODUCTION RESPONSE--WESTERN REGIONS

Five regional farms located in irrigated valleys of Montana have been defined for the purpose of estimating a long run supply response for sugar beets. This chapter describes two of these regional farms which are located in the western part of Montana. The 1980 regional sugar beet supply estimates are presented for both regions.

Area Under Study

Two sugar beet production areas are considered in this section. Regional Farm IV is represented by the sugar beet growers in Ravalli and Missoula counties (Figure 17). This area represents the former American Crystal Sugar Company factory district. Sugar beets grown in Regional Farm IV are processed by the Great Western Sugar Company at Billings, 380 miles east of the region.

Regional Farm V is located in Broadwater County, east of Regional Farm IV and west of Regional Farm III. Sugar beet growers in Region V also ship their beets to the Great Western refinery at Billings for processing.

Both Regions IV and V are located in mountainous country. The narrow Bitterroot Valley lies between two mountain ranges that reach 8,800 feet. The valley floor is 3,500 feet above sea level. The Townsend Basin in Broadwater County is nearly 4,000 feet above sea level.

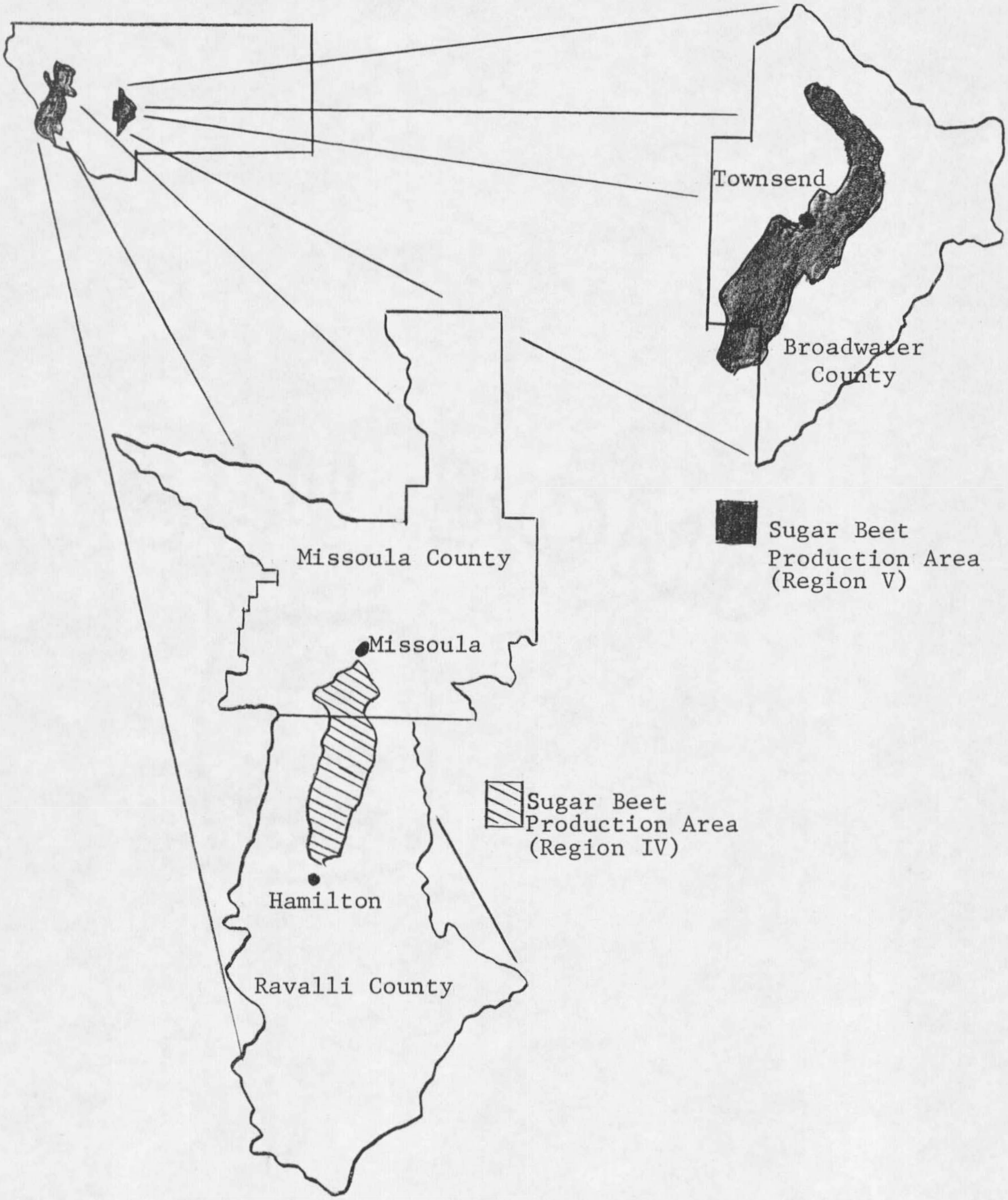

Figure 17. Regional Farms IV and V, Western Montana.

Water

The sugar beet growers in Regional Farm IV (Ravalli County) obtain irrigation water from the Bitterroot drainage. The Bitterroot River flows through the center of the Bitterroot Valley in a northerly direction. Some perennial flow streams also provide irrigation water. All irrigation units in the Bitterroot Valley are operated as private ditch companies in cooperation with the Montana State Water Conservation Board.

The primary source of water in Regional Farm V (Broadwater County) is the Missouri River. The Broadwater Water Users Association in cooperation with the Montana State Water Conservation Board have a dam on the Missouri River at Toston, Montana. Water diverted at Toston is used in the Townsend Basin and on the east side of Canyon Ferry Reservoir. Water from the Missouri River is also the source for the Crow Creek Irrigation Project managed by the Bureau of Reclamation. The Crow Creek unit serves the farms west and south of Townsend.

Climate

Regional Farm IV at Ravalli County is characterized by cool summers, relatively mild winters, and minimal amounts of wind. Temperatures average 68 degrees Fahrenheit in the summer and 25 degrees Fahrenheit in the winter with a temperature range of 100 degrees to 40 degrees below zero. The average length of the growing season is 122 days. However, in the last 20 years there have been three growing seasons with less than 95 days. The average annual precipitation is 11.17 inches of which 5.5

inches falls during the growing season. However, mountain areas bordering the Bitterroot Valley receive much more moisture. 1/

Regional Farm V in the Townsend Basin has low rainfall, extreme temperature ranges, relatively low humidity, many sunny days, and strong spring winds. The July temperature averages 67 degrees. Temperatures range from 100 degrees to 49 degrees below zero. The length of the growing season averages 104 days with a range of 73 to 148 days. The average annual rainfall is 11.50 inches with 65 percent (7.5 inches) falling during the growing season (Table XLVIII).

TABLE XLVIII. CLIMATE DATA, REGIONAL FARMS IV AND V. a/

Region	Annual Normal Precipitation	Growing Season Precipitation	Average Number of Days Between Freezing Temperatures
	(inches)	(inches)	
Region IV	11.17	5.50	122
Region V	11.50	7.50	104

a/ Montana Agricultural Statistics, Montana Department of Agriculture and United States Department of Agriculture, Helena, Montana.

The Soil Conservation Service has identified and classified 16 soil associations in Ravalli County, four of which are often planted to sugar

1/ Montana Agriculture Statistics, Montana Department of Agriculture and the United States Department of Agriculture, Helena, Montana, Vol. 2-11.

beets and other irrigated crops. These soil associations are Chamokane-Slocun located in the flood plain and low terraces; Hamilton-Corvallis-Grantsdale, Lone Rock-Slocum and Lolo located on the fans and terraces. Among the soils best adapted to sugar beet production are the Hamilton and Corvallis loams, Burnt Fork loams, Amsterdam silt loams and Bitterroot silt loams. These soils are relatively level, deep, well drained and generally dark colored. 2/

A total of 33 soil types have been classified in Region V. These soils were classified prior to the introduction of sugar beets and, therefore, very little has been published concerning the capabilities of the soils in the region. The Soil Conservation Service reported that 1,993 acres of 2S irrigated land was planted to row crops in 1966. 3/ It is thought that Amsterdam, Berthoud, Manhattan, and Avalanche loams constitute the majority of the irrigated cropland in the region.

Crops and Yields

The irrigated crops grown within the bounds of Regional Farm IV are corn silage, sugar beets, wheat, oats, barley, dry peas, dry beans, alfalfa, and potatoes. The number of acres planted and the yields of irrigated crops for the region are reported in Table XLIX.

2/ Soil Survey Bitterroot Valley Area, Montana, U.S.D.A., S.C.S., and Montana State Agriculture Experiment Station, May 1959, pp. 11-38.

3/ Soil Conservation Service soil classification 2S is identified through four numbers 2S, $2S_2$, $2S_3$, and $2S_4$; these soils are generally gently sloping to level, deep, loamy, well drained, and dark colored. The one through four classifications suggest the subsurface and surface soil plant material ranging from clay pans, calcarous, to granitic.

TABLE XLIX. IRRIGATED CROPS OF REGIONAL FARMS IV AND V, ACRES HARVESTED AND AVERAGE YIELDS, 1965. a/

Irrigated Crop	Region IV		Region V	
	Acres Harvested	Average Yields	Acres Harvested	Average Yields
Sugar beets	1,960	12.7 tons	1,705	8.2 tons
Corn grain	NA	NA	NA	NA
Dry beans	NA	NA	NA	NA
Winter wheat	500	55.0 bu.	400	50.0 bu.
Durum wheat	300	35.5 bu.	NA	NA
Spring wheat	800	51.0 bu.	4,500	36.0 tons
Corn silage	500	17.0 tons	200	20.0 bu.
Oats	2,200	64.0 bu.	1,000	61.0 bu.
Barley	3,700	78.0 bu.	2,100	55.0 bu.
Potatoes	401	210.0 cwt.	528	145.0 cwt.
Wild hay	5,200	1.35 tons	3,200	1.5 tons
Alfalfa hay	19,800	3.05 tons	17,500	3.0 tons
Flax seed	NA	NA	200	17.5 bu.

a/ Montana Agricultural Statistics, Vol. XI, United States Department of Agriculture, SRS, Helena, Montana, August 1967, pp. 22-62.

Sugar beet production in Regional Farm IV has varied over the years. According to McArthur, 4,160 acres of sugar beets were planted in 1961 while only 1,300 acres were contracted in 1966. 4/ McArthur indicated that sugar beet yields varied widely and depended to a large extent on the

4/ J. Wayne McArthur, "Economic Impacts of Some Alternative Uses for Resources Historically Devoted to Sugar Beet Production and Refining, Ravalli County, Montana, 1965". Unpublished manuscript, Natural Resource Economics Division, E.R.S., U.S.D.A., Salt Lake City, Utah, October 1966.

climatic conditions of the region. 5/ In Region IV sugar beet yields have been reported to range from 4.3 tons per acre to 21.4 tons per acre over a five-year period (1961-65). Sugar content of Regional Farm IV beets has varied from 16.97 percent in 1960 to 15.26 percent in 1965. 6/

The irrigated crops grown in Regional Farm V are wheat, alfalfa, hay, barley, and sugar beets. There also appears to be a growing interest in corn silage production (Table XLIX).

The irrigated crops of Regional Farm IV and V are generally grown in rotation with other crops. Cropping sequence suggested by the growers of Region IV (Ravalli County) are reported in Table L. Cropping patterns used in Regional Farm V were not ascertained. 7/

Cropping patterns are used to avoid disease and nematodes. The sugar beet growers of Regional Farm V have not experienced nematode problems. Indications are that sugar beets are grown in succession up to six years on the same fields. Region IV growers have experienced disease and nematode problems which have necessitated cropping sequences.

5/ Ibid., p. 6. McArthur reported that 73 percent of the variations in yield was due to climatic conditions.

6/ Ibid., p. 12.

7/ The growers of Regional Farms IV and V were not interviewed for this study. Secondary data concerning irrigated agriculture was used where it was available for both regions.

TABLE L. REPORTED CROPPING PATTERNS USED BY GROWERS--REGIONAL FARM IV, 1965. a/

Cropping Sequence					Number of Years
Barley	3 alfalfa	wheat	beets		6
Barley	2 alfalfa	corn sil	wheat	potatoes	6
Wheat	2 alfalfa	corn sil	wheat	potatoes	6
Wheat	3 alfalfa	wheat	beets		6
Wheat	2 alfalfa	corn sil	wheat	wheat	6
Wheat	2 alfalfa	wheat	wheat		5
Wheat	2 alfalfa	corn sil	wheat		5
Wheat	2 alfalfa	wheat			4
Wheat	2 alfalfa	dry peas	wheat		5

a/ McArthur, "Economic Impacts of Some Alternative Uses for Resources Historically Devoted to Sugar Beet Production and Refining, Ravalli County, Montana, 1965", op. cit., pp. 30-41.

Livestock

Farmers on irrigated farms in Regional Farm IV and V raise livestock for Montana, western and eastern markets. Livestock numbers for both regions are reported in Table LI.

TABLE LI. LIVESTOCK REPORTED ON FARMS IN REGIONS IV AND V, 1966. a/

Livestock	Region IV	Region V
All cattle and calves	56,400	34,300
Milk cows	4,700	300
Hogs and pigs	4,200	1,500
Chickens	76,000 b/	14,000 b/
Sheep	9,300	7,000

a/ Montana Agricultural Statistics, Vol. SI, Montana Department of Agriculture and U.S.D.A., Helena, Montana, August 1967.

b/ 1965 data.

Labor

It is thought that the labor required to perform cropping operations and livestock care comes from family farms and local high school students. Sugar beets are hoed and thinned by skilled labor provided by the sugar companies from non-Montana labor markets.

Sugar Beet Supply Model: Regional Farms IV and V

Primary data was not gathered for the purpose of constructing a linear programming sugar beet supply response model. Alternative activities of the objective function are cropping patterns reported by McArthur and cropping sequences thought to be feasible for the area. Net revenue per crop rotation activity was based on the costs and returns determined for other portions of the state. 8/ Prices used were common to Montana.

Fifteen cropping sequences thought to represent cropping patterns in region IV have been specified (Table LII). The crop rotations are assumed to be alternatives facing sugar beet growers during 1980.

There were 37,898 irrigated acres of cropland in the Region IV inventory during 1966. It is expected that an additional 8,430 acres of tillable cropland will be available for production by 1980 (Table LIII).

The Regional Farm V supply response model is similar to the four other regional models described earlier. Alternative cropping patterns,

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8/ Budget studies made by McArthur were used where applicable as well as the costs of production determined in Regions I, II, and III.

TABLE LII. CROP ROTATION ALTERNATIVES, REGIONAL FARM IV, 1980.

Rotation Number	Cropping Sequence						Number of Years
1	Barley	4 alfalfa	wheat	beets			7
2	Wheat	3 alfalfa	corn sil	beets			6
3	Wheat	3 alfalfa	wheat	beets			6
4	Barley	3 alfalfa	peas	beets			6
5	Barley	3 alfalfa	wheat	peas	beets		7
6	Barley	3 alfalfa	beans	beets			6
7	Wheat	beans	wheat	peas	wheat	beets	6
8	Barley	3 alfalfa	corn sil	wheat	potatoes		8
9	Wheat	3 alfalfa	corn sil	potatoes			6
10	Wheat	3 alfalfa	corn sil				5
11	Wheat	2 alfalfa	wheat				4
12	Wheat	3 alfalfa	peas	wheat			6
13	Barley	3 alfalfa	beans	peas			6
14	Wheat	3 alfalfa	peas	potatoes			6
15	Wheat	3 alfalfa	beans	potatoes			6

TABLE LIII. INVENTORY OF LAND IN REGIONAL FARM IV, BY LAND CLASS AND NEW IRRIGATION PROJECTS, 1980.

	Land Classes				
	Class 1	Class 2	Class 3	Class 4	Totals
	(acres)				
1966 inventory	5,455	17,548	8,988	5,907	37,898
State projects 1980 a/	1,214	3,903	1,998	1,315	8,430
Bur. of Reclam. 1980 a/	-----	------	-----	-----	------
Totals	6,669	21,451	10,986	7,222	46,328

resources restricting sugar beet production, and appropriate input-output coefficients are specified in the model.

Twelve cropping alternatives including the net revenue expected in 1980 from producing the crop sequence are specified (Table LIV).

TABLE LIV. CROP ROTATION ALTERNATIVES, REGIONAL FARM IV, 1980.

Rotation Number	Cropping Sequence						Number of Years
1	Barley	3 alfalfa	beets	beets	beets		7
2	Wheat	3 alfalfa	barley	beets	beets		7
3	Wheat	3 alfalfa	beets	beets	beets	beets	8
4	Wheat	3 alfalfa	corn sil	beets	beets		7
5	4 alfalfa	wheat	beets	beets			7
6	4 alfalfa	beets					5
7	Barley	3 alfalfa	potatoes				5
8	Wheat	3 alfalfa	potatoes				5
9	Wheat	3 alfalfa	corn sil	corn sil			6
10	Wheat	3 alfalfa	corn sil	potatoes			6
11	4 alfalfa	wheat	potatoes	potatoes			7
12	4 alfalfa	potatoes	potatoes				6

Land and labor are among the limited resources that restrict the production of sugar beets in Region V. In 1966 there were 12,500 acres of land in Region V under irrigation. A new Bureau of Reclamation project referred to as the Jefferson-Whitehall Unit is scheduled to be completed by 1980. Water from the Beaverhead and Big Hole drainages would be stored at the proposed Reichle Dam site near Glen, Montana. Water would be diverted to the Townsend Basin (Region V) for irrigation purposes. It is thought that an additional 53,980 acres of irrigated land would be brought into production as a direct result of the Bureau project (Table LV). 9/

9/ Report on Jefferson and Whitehall Units, Montana, United State Department of the Interior, Bureau of Reclamation, Upper Missouri Projects Office, Great Falls, Montana, August 1965. At this writing the proposed Jefferson-Whitehall Unit has not been approved by the Congress of the United States. There has been a great deal of opposition to the project by sportsmen groups and some ranchers. There may be question as to the feasibility of the project based on the short growing seasons often times experienced in Region V.

When the Jefferson-Whitehall unit is completed a total of 66,480 acres of land would potentially be available for sugar beet production.

TABLE LV. INVENTORY OF LAND IN REGIONAL FARM V, BY LAND CLASS AND NEW IRRIGATION PROJECTS, 1980.

	Land Classes				
	Class 1	Class 2	Class 3 (acres)	Class 4	Total
1966 inventory	812	5,287	6,213	188	12,500
State projects 1980	0	0	0	0	0
Bur. of Reclam. 1980 a/	3,998	22,806	26,303	873	53,980
Totals	4,800	28,093	32,516	1,061	66,480

a/ Bureau of Reclamation projects are expected to be completed by 1980.

Supply Response--Regions IV and V:

Two supply response models were used to estimate sugar beet production in each region: (1) regional farm response and (2) regional farm response including land use restrictions.

Model I--Regional Farm IV: Based on the model assumptions and specifications there would be no sugar beet production in Region IV at prices ranging from \$14.00 to \$21.50 per ton. In all solutions, Rotations 9 and 15 dominated the basis. Crop Rotations 9 and 15 consist of grain, alfalfa, and potatoes. Rotation 9 also included corn silage while Cropping Sequence 15 included dry beans. Cropping patterns including potatoes were much more competitive than those containing sugar beets at specified prices.

Model II--Region IV: Model II differed from Model I in that the former included a land use limitation. That is, no one crop rotation was allowed on more than one-fifth of the available irrigated land. At $17.50 per ton, 2,123 acres of sugar beets should be produced (Table LVI and Figure 18). The response consisted of Rotations 2, 7, and 8, and non-sugar beet Cropping Sequences 9 and 15. At beet prices above $17.00 Crop Rotation 2 replaced number 15 on Land Type 4. Rotation 2 also replaced Rotation 9 on Land Type 1 at a beet price of $19.50 per ton.

TABLE LVI. SUGAR BEET SUPPLY RESPONSE FOR REGIONAL FARM IV, 1980, INCLUDING LAND USE LIMITS.

Price Per Ton	Supply Response
(Dollars)	(Acres)
14.00	1,651
14.50	1,701
15.00	1,701
15.50	1,701
16.00	1,818
16.50	1,818
17.00	1,818
17.50	2,123
18.00	2,123
18.50	2,124
19.00	2,124
19.50	2,409
20.00	2,409
20.50	2,409
21.00	3,292
21.50	3,296

Model I--Region V: Broadwater County farmers should produce 812 acres of sugar beets in 1980 at beet prices above $20 per ton (Table LVII and Figure 18). Cropping patterns that include alfalfa and potatoes are much more competitive than crop rotations consisting of sugar beets.

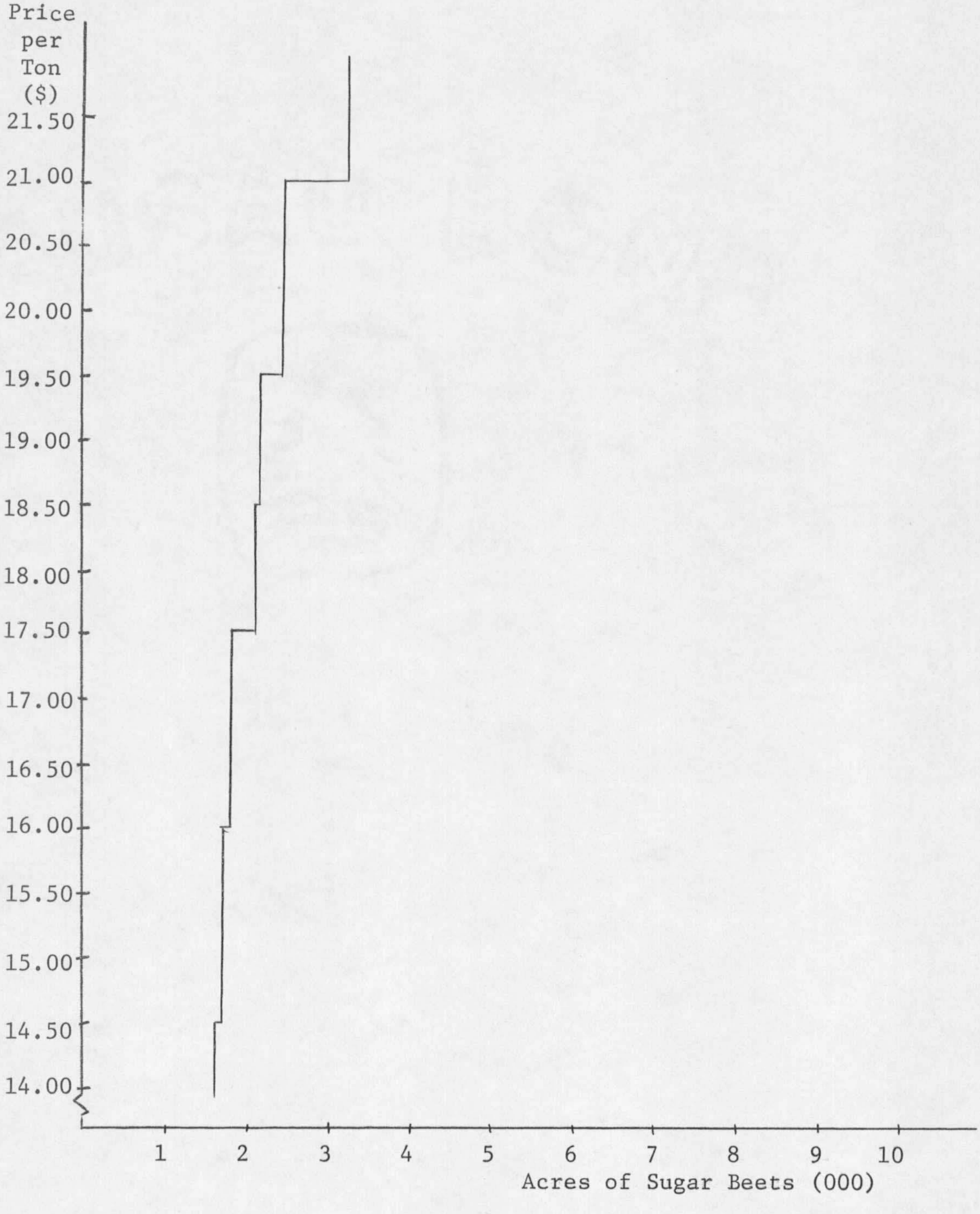

Figure 18. Sugar Beet Supply Response, Regional Farm IV, 1980, Including Land Use Limits.

TABLE LVII. SUGAR BEET SUPPLY RESPONSE FOR REGIONAL FARM V, 1980.

Price Per Ton	Supply Response
(Dollars)	(Acres)
14.00-19.50	0
20.00	812
20.50	812
21.00	812
21.50	812

Crop Rotation 12, which included four years of alfalfa and two years of potatoes would be produced on all the available land in the region at beet prices ranging from $14.00 to $19.50 per ton. Rotation 3 (wheat, 3 alfalfa, 4 sugar beets) replaced Cropping Sequence 12 on Land Type 4 (poorest quality) at $20.00 per ton for beets.

Model II--Region V: The regional model was respecified with land use limits because it is not reasonable to expect that one rotation would be used by the many farmers in Broadwater County. Furthermore, there is a question concerning whether the length of the growing season would sustain potato production.

The land use restriction limited each cropping sequence to a maximum utilization of one-fifth of the available irrigated land. At $17.50 per ton for beets about 1,988 acres of sugar beets would be produced (Table LVIII and Figure 19). Rotations 11 and 12 which included potatoes, were found in each variable price optimum solution from $14.00 to $21.50.

TABLE LVIII. SUGAR BEET SUPPLY RESPONSE FOR REGIONAL FARM V, 1980, INCLUDING LAND USE LIMITS.

Price Per Ton	Supply Response
(Dollars)	(Acres)
14.00	1,514
14.50	1,514
15.00	1,856
15.50	1,856
16.00	1,856
16.50	1,856
17.00	1,856
17.50	1,988
18.00	1,988
18.50	7,722
19.00	11,786
19.50	11,786
20.00	13,593
20.50	13,735
21.00	13,735
21.50	13,743

By increasing the price of beets all rotations containing sugar beets would be alternatives to non-beet cropping patterns except Rotation 6. In summary, those rotations containing potatoes are the most profitable cropping sequences for Region V.

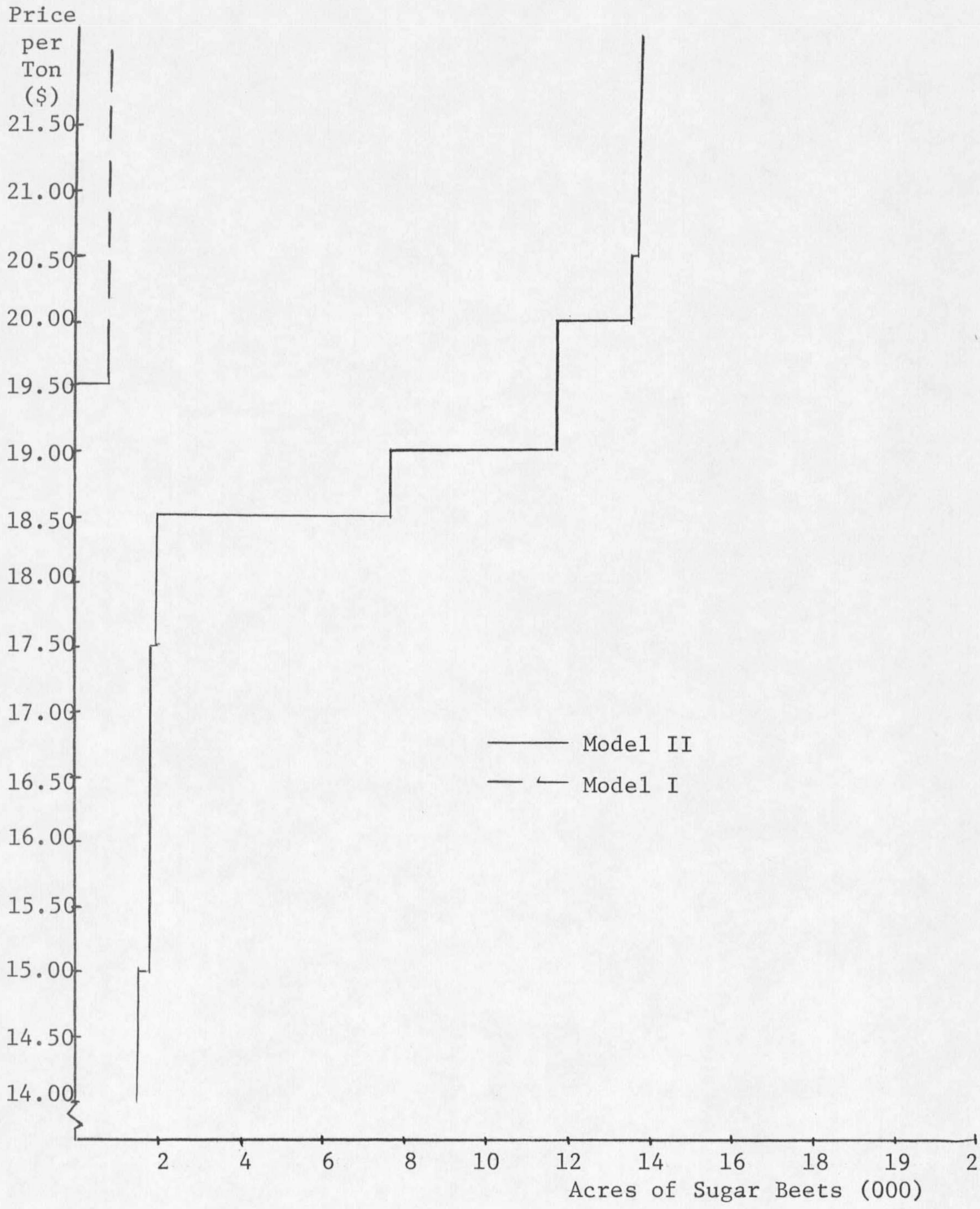

Figure 19. Sugar Beet Supply Responses for Regional Farm V, 1980, Comparison of Models I and II.

CHAPTER VIII

AGGREGATE MONTANA SUGAR BEET SUPPLY RESPONSE--1980

Aggregate 1980 Montana sugar beet supply response has been estimated by using three models: (1) regional farms, (2) regional farms with land use limitations, and (3) typical farms.

Regional Farms

The Montana sugar beet supply for 1980 was formed by horizontally summing the supply response generated in five regional farms (Table LIX and Figure 20). At the projected 1980 sugar beet price of $17.50 per ton it is estimated that 171,481 acres of sugar beets would be planted, on approximately 21 percent of the available irrigated land. Biologically, 171,481 acres of sugar beets in the specified regions of Montana during 1980 is feasible. Other crops, planted on 79 percent of the land, would be helpful in minimizing yield losses due to disease, insects, nematodes, and soil depletion.

Even though the sugar beet response estimate is biologically feasible in the aggregate, a closer examination of the response data suggests that the estimated supply exceeds minimum biological requirements in one region. As previously pointed out, the beet supply response in Region II required 45 percent of the available land while the Region III response would occupy 17.5 percent of the available irrigated land. Even though the supply estimate in Region II is feasible for at least one year, continued sugar beet cropping on 45 percent of the land would eventually be detrimental to yields. At $17.50 per ton, sugar beets would not be grown in Regions I and IV. The total supply estimate comes from Regions II, III, and V.

TABLE LIX. SUGAR BEET SUPPLY RESPONSE BY REGION FOR MONTANA IN 1980--MODEL I ANALYSIS.

Price per Ton	Regional Farm Supply Responses					Total Montana Response
	Region I (East Central)	Region II (South Central)	Region III (North and West Central)	Region IV (Western)	Region V	
(Dollars)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)
14.00		0	32,798		0	32,798
14.50		0	40,097		0	40,097
15.00		0	54,509		0	54,509
15.50		0	60,315		0	60,315
16.00		8,828	60,315		0	69,143
16.50		8,828	62,233		0	71,061
17.00		8,828	62,233		0	71,061
17.50		109,248	62,233		0	171,481
18.00		109,248	62,233		0	171,481
18.50		116,869	87,045		0	203,914
19.00		118,759	111,491		0	230,250
19.50		118,759	111,491		0	230,250
20.00		118,759	111,491		812	231,062
20.50		118,759	116,747		812	236,318
21.00		118,759	119,147		812	238,718
21.50		118,759	119,147		812	238,718

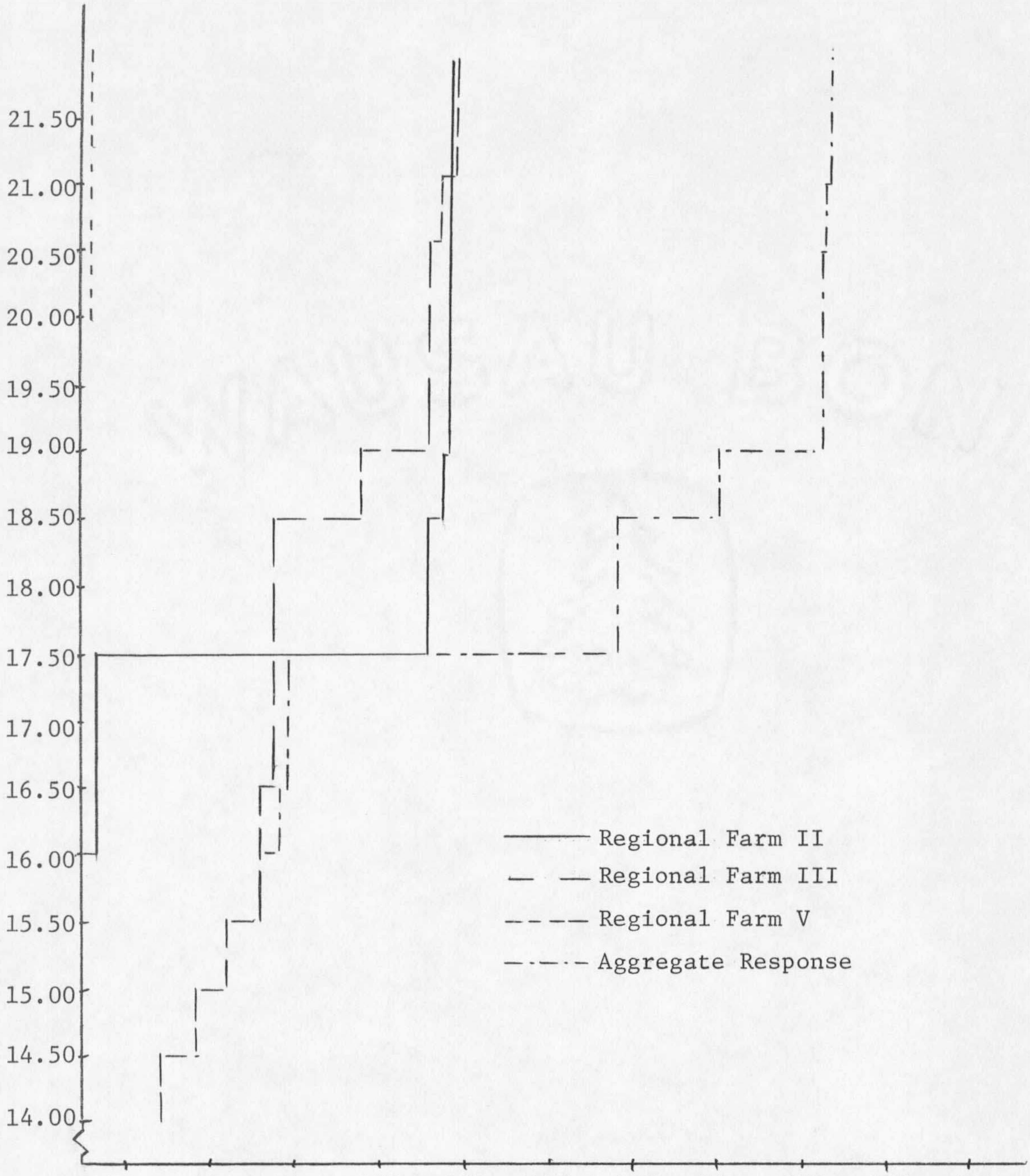

Figure 20. Sugar Beet Supply Reponse by Region in Montana for 1980 - Model I Analysis.

Regional Farms with Land Use Limits

The second 1980 aggregate Montana sugar beet supply estimate was made with a model designed to limit the specified crop rotation to a maximum of one-fifth of the available land at all sugar beet prices (Table LX and Figure 21). The sugar beet response resulted in 127,597 acres at the projected 1980 beet price. Nearly 16 percent of all the available irrigated land in the five regions would be planted to sugar beets.

The sugar beet supply response of the restricted land use model at $17.50 per ton is 43,884 acres less than the response generated at the same price with Model I. The difference is attributed to the land use limitations placed on the specified cropping sequences in Model II.

Model I had a lower aggregate response at sugar beet prices below $17.00 than Model II. However, at prices above $17.00, Model I sugar beet supply estimates were larger than those of Model II. This phenomenon is due to the upper land use limit in Model II. At the lower beet prices, rotations containing potatoes were more competitive than crop sequences including sugar beets. Beets were forced to poorest land qualities at the lower prices in Model I. However, in Model II, the more competitive non-sugar beet rotations were limited to the amount of land designated. Once land use upper limits were filled, the next best alternative rotations would enter the optimum solutions up to their land limit or until all land was used up. Usually, the next best alternative to the potato rotations were crop sequences consisting of sugar beets.

TABLE LX. SUGAR BEET SUPPLY RESPONSE BY REGION FOR MONTANA, IN 1980, MODEL II ANALYSIS, INCLUDING LAND USE LIMITS.

Price per Ton	Regional Farm Supply Response					Total Montana Response
	Region I (East Central)	Region II (South Central)	Region III (North and West Central)	Region IV (Western)	Region V	
(Dollars)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)
14.00	3,487	59,254	42,106	1,651	1,514	108,012
14.50	3,487	64,006	44,488	1,701	1,514	115,196
15.00	3,487	65,723	44,488	1,701	1,856	117,255
15.50	3,488	67,348	44,497	1,701	1,856	118,890
16.00	3,488	67,348	44,505	1,818	1,856	118,890
16.50	3,488	68,448	44,505	1,818	1,856	120,115
17.00	3,488	69,420	47,215	1,818	1,856	123,797
17.50	5,052	71,219	47,215	2,123	1,988	127,597
18.00	5,409	71,219	52,363	2,123	1,988	133,102
18.50	5,409	74,139	52,365	2,124	7,722	141,759
19.00	5,410	74,139	68,946	2,124	11,786	162,405
19.50	6,192	75,040	72,721	2,409	11,786	168,148
20.00	6,192	75,844	77,481	2,409	13,593	175,519
20.50	6,192	76,763	77,481	2,409	13,735	177,463
21.00	9,397	76,763	77,481	3,292	13,735	180,668
21.50	11,421	76,763	79,089	3,296	13,743	184,312

Above $17.00 per ton in Model I, rotations including sugar beets are the most competitive and, therefore, dominate the solutions. However, in Model II, sugar beet rotations are restricted by the land use limit. Therefore, at any price above $17.00 there are fewer beets than in Model I because potato rotations (now the next best alternatives) enter the solutions on the remaining land.

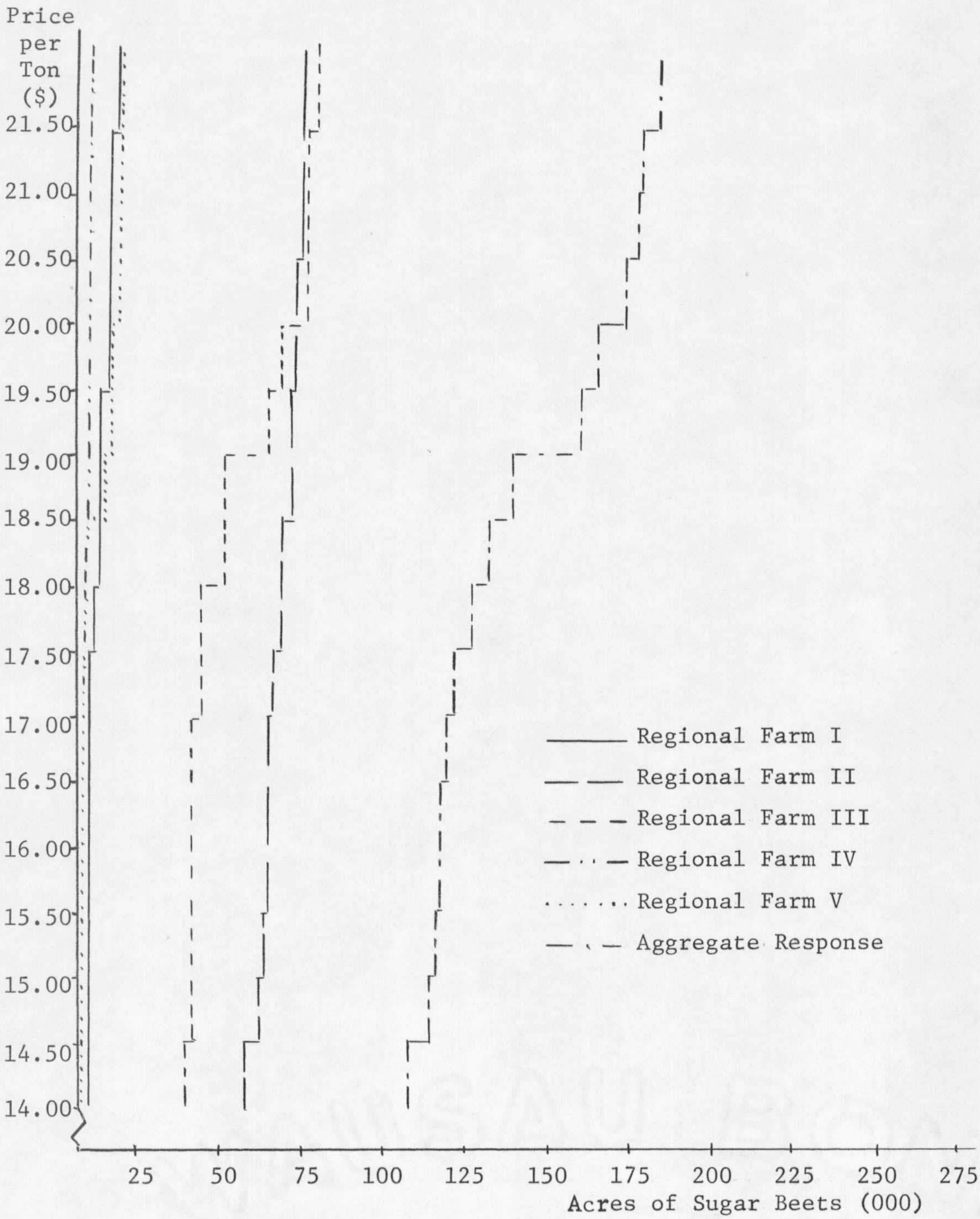

Figure 21. Sugar Beet Supply Response by Region in Montana for 1980 - Model II Analysis, Including Land Use Limits.

Comparison of Regional and Typical Farm Supply Response Models

Three of the regional sugar beet supply responses were aggregated and compared to the aggregate supply response estimated by using typical farms as the responding unit. The supply response from Regional Farms I, II, and III (Models I and II) are compared to the aggregated typical farm response (Table LXI and Figure 22).

At $17.50 per ton for sugar beets, the expanded typical farm supply estimates exceeded the regional response (Model I and Model II) by 9,948 and 53,832 acres respectively. At sugar beet prices above $17.50 the typical farm sugar beet supply estimates were larger than either regional model responses.

The models were specified in such a way that the proper comparison would be that of Regional Model I and the aggregate typical farm response of Model III. Regional Model II included the land use limits that neither of the other models possessed.

As shown in Figure 22, the typical farm response is consistently to the right of the Model I estimates. Assuming that Model I is correctly specified, the typical farm response appears to overestimate the supply of sugar beets in Montana.

In comparing the aggregate sugar beet supply responses of Model I to that of Model III, one can conclude that Model I is a feasible long-run sugar beet supply response from a biological standpoint. Twenty-one percent of the total specified land in Montana should be planted to sugar beets based on the program results of Model I and

TABLE LXI. COMPARISON OF THREE MONTANA SUGAR BEET SUPPLY RESPONSES FOR 1980, REGIONAL FARM, REGIONAL FARM WITH LAND USE LIMITS, AND AGGREGATE TYPICAL FARMS.

Price per Ton	Supply Response		
	Regional Model I	Regional Model II	Aggregated Typical Farm Model III
(Dollars)	(Acres)	(Acres)	(Acres)
14.00	32,798	108,012	45,411
14.50	40,097	115,196	79,683
15.00	54,509	117,255	101,157
15.50	60,315	118,890	102,631
16.00	69.143	118,890	134.236
16.50	71,061	120,115	173,677
17.00	71,061	123,797	176,396
17.50	171,481	127,597	181,429
18.00	171,481	133,102	189,220
18.50	203,914	141,759	222,588
19.00	230,250	162,405	261,071
19.50	230,250	168,148	262,059
20.00	231,062	175,519	262,059
20.50	236,318	177,463	271,949
21.00	238,718	180,668	271,949
21.50	238,718	184,312	271,949

23 percent in Model III at the equilibrium price in 1980. Both estimates are considered to be biologically feasible. Model I response, while appearing biologically feasible in the aggregate, may not be biologically possible in the long run in the individual regions. In Region II, (Southeastern Montana) at $17.50 per ton of beets, 45 percent of the available land should be utilized for beet production which is not feasible over a long period of time.

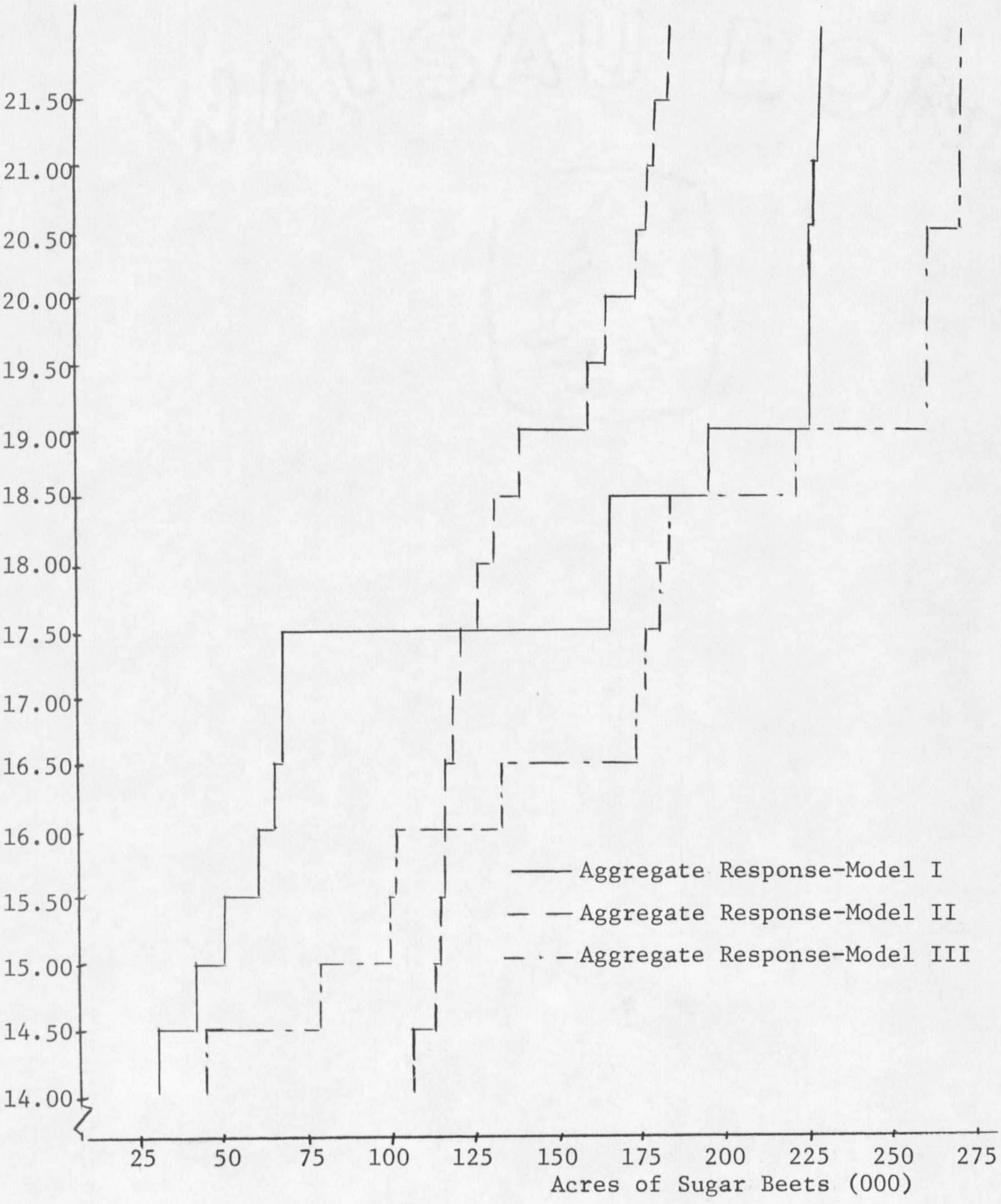

Figure 22. Comparison of Three Montana Sugar Beet Supply Responses for 1980; Regional Farm, Regional Farm with Land Use Limits, and Aggregate Typical Farms.

Model II, regional farms with land use limitations, appears to be the most desirable long run estimate of sugar beet production at $17.50 per ton. At this price, 16 percent of the land specified should be planted to sugar beets.

CHAPTER IX

BEET SUGAR PROCESSING IN MONTANA

Sugar Recovery

The recovery of sugar from beets took place in Montana on a non-commercial basis in 1898. 1/ The extraction of sugar from beets can be summarized in eight steps. Each of the processing steps are briefly discussed. 2/

(1) Sugar beets are harvested and stored in large piles near the refinery. A loading and conveyor system transports the beets to washing and scrubbing tanks for the purpose of removing soil and other debris from the beets.

(2) After scrubbing, the beets pass through large funnels and into rotary knives which slice them into "shoe string" like segments referred to as cossettes or chips.

(3) The cossettes enter large holding tanks where hot water permeates them. By the principle of osmossis, sugar juices are removed from the beet tissue. Two separate products emerge from the diffusion process,

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1/ See Appendix 3 for a history of the development of the beet sugar industry in Montana.

2/ P. M. Silin, Technology of Beet Sugar Production and Refining, U.S.D.A. and National Science Foundation, Washington, D. C., 1964; and John G. McIntosh, The Technology of Sugar, New York: D. Van Nostrand Company, 1903.

raw juice and beet pulp. The pulp (cossettes) are pressed dry and removed to other parts of the plant for processing into livestock feed. Raw sugar juices move on to the purification process.

(4) The purifying of raw juice, which contains 10 to 15 percent sugar, is completed in three steps. First, milk of lime is added to the solution which chemically makes the non-sugar substances insoluable. Secondly, carbon dioxide (CO_2) is bubbled through the raw juice which makes the milk of lime solution insoluble. Finally, the solution (milk of lime, raw juice, and carbon dioxide) is passed through a series of filters. The lime and non-sugars are filtered away from the remaining solution which is called thin juice.

(5) The thin juice is processed into thick juice by evaporation in a vacuum. Large quantities of steam are required to perform the evaporation process. Thick juice is filtered resulting in a solution called standard liquor which contains 50 to 65 percent sugar.

(6) Crystals are formed from the standard liquor. The standard liquor is boiled in large vacuum pans. Then pulverized sugar is injected into the liquor (seeding) which initiates sugar crystal development. The crystals or white fillmoss are allowed to grow to a specified size.

(7) High speed centrifugal machines separate the white fillmoss into brown syrup and the sugar crystals. The syrup is returned to the boiling or evaporation vats and eventually passed twice more through the centrifugal machines.

(8) White sugar crystals are subjected to warm then cool blown air. After this process, the dried sugar is stored in large silos and packaged for market.

Molasses is the name given to the white fillmoss after three passes through the centrifugal machines. Molasses does contain some sugar but it is not economically feasible to recover this sugar through normal refining methods. However, two methods have been developed to glean sugar from molasses. The first method is the Steffen process. Lime is added to the molasses forming an insoluble compound which is filtered out of the molasses and returned to the regular sugar making process. The second is the Barium hydroxide method which used on a small scale in the United States. Barium hydroxide and sugar form a precipitate which is filtered from the molasses and returned to the regular process.

Those factories which encorporate the Steffin process as well as the barium hydroxide procedure are able to recover more sugar per ton of beets sliced than those plants not using these methods. The Great Western Sugar Company refinery at Billings was initially constructed with the Steffen process as part of the sugar recovery procedure. Today both Holly Sugar Company refineries also use the Steffen process.

Beet Sugar Factory Input-Output Organization

A number of inputs are required to recover sucrose from sugar beets profitably. Among the important inputs are sugar beets, water, fuel, labor, and chemicals. The amount of sugar finally extracted from a ton of sugar beets depends upon the quality of the beets and the method used to recover sugar.

Sugar Beets:

Sugar beets must be of a high quality to ensure economic returns to the factory and grower. Quality refers to the ratio of sugar to impurities contained within the beet. Factory representatives are assigned specific beet districts and they work closely with growers to maximize sugar content. The Great Western Sugar factory averaged 16.90 percent sugar from 1906 to 1954. The range was 15.16 percent sugar in 1926-27 to 18.63 percent sugar in 1907-08. The average sugar content of beets harvested in Montana during 1967 was 17.60 percent.

Labor:

Sugar refining in Montana begins during October and often times lasts through January. The larger plants in the state hire seasonal labor for 125 days. The amount of labor required to extract sucrose from sugar beets is dependent upon the methods used in the process and the quality of the sugar beets. Kinsely reported that an average of .86 man hours per ton of sliced beets or .32 man hours per 100 pounds of sugar produced was required during 1952. 3/

3/ Robert T. Kinsely, Beet Sugar Refining, BLS Report No. 6, Department of Labor, February 1953, p. 12.

During the 1963 sugar campaign in Montana, four plants required 1,293,000 man hours, or 1.10 man hours, per ton of beets sliced to produce sugar. During 1965, 1,307,000 man hours were required to slice 748,000 tons of beets or 1.74 man hours per ton of beets sliced. The average number of production workers employed in four Montana sugar factories during 1958-1965 was 585. An additional 79 employees were required for administrative work (Table LXII).

TABLE LXII. LABOR IN THE MONTANA BEET SUGAR PROCESSING INDUSTRY FOR SELECTED YEARS, 1955, 1958, 1964, and 1965. a/

Year	Number of Factories	Total Employees	Production Workers	Annual Average Wage Per Worker	Average Wage Per Worker Per Hour (US)
1958	4	594	594	--	2.07
1963	4	665	580	5,194.82	2.44
1964	4	686	611	5,898.52	2.49
1965	4	640	564	5,829.78	2.59
Averages		664	585	5,641.04	2.51

Water

The sugar recovery process requires large amounts of quality water. The amount of water needed in any given plant depends upon the recirculation system in the plant. The flow of water in the sugar making process is illustrated in Figure 23 for a typical plant incorporating the Steffen process. Water use estimates were reported for sugar refining plants during 1954 and 1959 (Table LXIII).

WATER TECHNOLOGY OF THE INDUSTRY

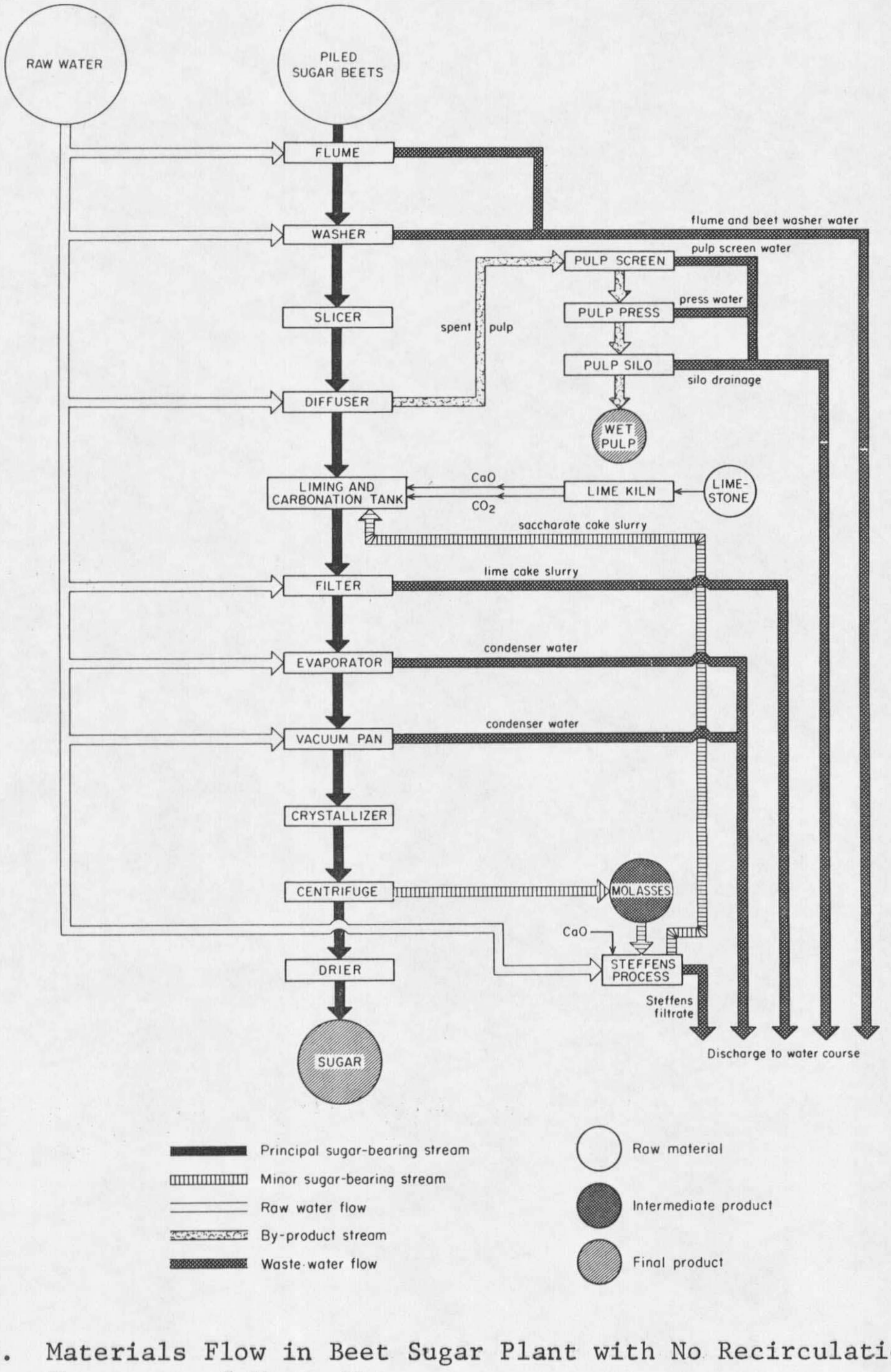

Figure 23. Materials Flow in Beet Sugar Plant with No Recirculation or Treatment of Waste Waters.

TABLE LXIII. ESTIMATED WATER USE--TYPICAL SUGAR REFINING FACTORY, 1958-59.

Item	Gallons of Water Per Ton of Sugar Beets
Intake	2,600
Gross Use	4,400
Discharge Total	2,400
Treated in Plant	900
Untreated	1,500
Untreated Discharge to Public Sewer	--
Untreated Discharge to Surface Water, Ground or Wells	1,500

a/ Source: George O. G. Lof and Allen V. Kneese, The Economics of Water Utilization in the Beet Sugar Industry, Baltimore: Johns Hopkins Press, 1968, p. 14.

Young and Asmus estimated that the sugar processing industry in Montana used 3.2 billion gallons of water in 1966. 4/ This amounted to an estimates 3,116 gallons per ton of beets sliced in four Montana beet sugar factories (Intake water, not gross use). Because the plants in Montana are Steffen refineries it is expected that gross use of water per ton of beets sliced is near 5,000 gallons.

Fuel

Fuel is required to generate steam which, in turn, is used estensively throughout the sugar recovery process. The evaporation stage requires

4/ Kenneth Young and Edward B. Asmus, "Municipal, Industrial, and Agricultural Water Use in Montana, 1966", unpublished paper, Department of Agricultural Economics, Montana State University, Bozeman, Montana, 1968.

the greatest amount of steam. Multi-steam utilitzation plants require 6-7 KG's of coal fuel per 100 KG of beets sliced. 5/ (Approximately 132 pounds of coal per 220 pounds of beets or nearly 1,300 pounds of coal per ton of beets sliced.)

Also, fuel is required in the pulp drying operation. It is estimated that four KG's of coal is required to dry pulp from 100 KG's of beets (88 pounds of coal per ton of beets). 6/ Furthermore, the burning of lime rock to generate corbon dioxide (CO_2) requires considerable amounts of fuel. Temperatures of 1,000 degrees Centigrade to 1,100 degrees Centigrade are required to generate CO_2 from limestone ($CaCO_2$). It is suggested that 10 to 20 pounds of coke per ton of beets is required to achieve the desired temperatures. 7/

Other chemicals, compounds, and materials are required in refining sugar beets. Limestone is used at a rate of 100 pounds per ton of beets processed. Sulphur, activated carbon, and filter cloth are used in the purifying stage. In addition, string and various sizes of sugar bags are used to prepare the final product for market.

5/ Silin, Technology of Sugar Beet Production and Refining, op. cit., p. 275.

6/ Ibid., p. 378.

7/ Young, "An Economic Study on the Eastern Beet Sugar Industry", op. cit., p. 118.

Sugar Refining Capacity in Montana--1980

Assuming that the potential sugar beet production for 1980 at $17.50 per ton is realized (127,000 acres), the refining capacity within the state would have to expand. There are four ways that the sugar industry in Montana could enlarge its capacity. There are (1) increase these number of plant operating days, (2) construct new factories, (3) expand the existing plant facilities and (4) develop thick juice storage facilities.

Processing Season:

One way that Montana's beet sugar capacity could be expanded is to increase the number of days that the factories operate during the sugar campaign. At the end of 1969 it is expected that the daily capacity of the sugar industry in Montana will be close to 9,000 tons of beets sliced per day. 8/ If each factory were to operate an average of 125 days, 1,125,000 tons of beets could be processed. At a yield of 17 tons per acre (1980 projected average yield) 66,176 acres of beets could be harvested and processed. The projected 1980 sugar beet supply response at $17.50 per ton is 127,000 acres (Model II) or 60,824 acres (1,034,008 tons) more than the existing capacity could process in 125 days. Some believe

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8/ Current expansion programs at the beet sugar plants in Montana should increase the daily beet slicing capacity from 8,400 to 9,000 tons by the end of 1969.

that the extra sugar beet acreage could be harvested and processed by operating the factories for more than 125 days.

It is estimated that 239 processing days or 114 more days than currently are used would be required to process 127,000 acres of sugar beets with the existing daily capacity of 9,000 tons. Adding 114 days to the processing season at best would be difficult.

The primary restriction in operating sugar factories in Montana for 240 days is centered in the storage of sugar beets. The sugar beet root does not die after harvest unless it is subjected to extreme heat or cold. Under the right environmental conditions, beets in storage will undergo normal respiration, i.e., oxygen (O_2) is absorbed by the root tissue while carbon dioxide (CO_2) and water (H_2O) are given off in the form of heat. In the process, sugar stored in the beet is used up. 9/ Sugar content of the beet diminishes as respiration continues in the storage stage. Silin estimated that average daily sugar loss of beets in storage is .01 percent. In 150 days 1.5 percent of the beet weight is lost.

Heat, water, and carbon dioxide from respiration causes other problems. Water in vapor form condenses to liquid thereby covering the beets and making a favorable environment for fungus growth. Also, occasionally "hot spots" develop inside the beet piles. If these spoilage areas are not discovered, rotting will spread causing a rapid

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9/ Respiration in sugar beets can be written as:
$C_{12}H_{22}O_{11} + 12O_2 \longrightarrow 12CO_2 + 11H_2O + \text{energy}$
Sugar + Oxygen yields Carbon Dioxide + Water + Heat (enough heat to raise the temperature of 62.5 pounds of water from 98 degrees Fahrenheit to 212 degrees Fahrenheit.

rapid decrease in sugar content. Studies have shown that temperatures both within and outside beet piles influence the rate of respiration and heat output more than other environmental factors. 10/

In Montana, the beet ripening process and the climatic conditions within the growing areas necessitates that beets be removed from the ground between October and the middle of November. The factories cannot keep up with the harvest so beets are stock piled for later processing. 11/ It has been estimated that sugar beets will be stored nearly 140 days during the 1968 campaign at Hardin, Montana. 12/

There are alternative processes that may be used to preserve sugar beets in storage. Such methods may be feasible at Montana sugar factory sites to increase storeability and, therefore, increase the number of plant operating days. These storage methods include freezing or dehydration of the beets. Factory seasons in some areas of Russia have been extended to 200 days by incorporating this storage technology. 13/ It was

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10/ R. H. Cottrell, Beet-Sugar Economics, Claxton Printers, Caldwell, Idaho, 1952, p. 222.

11/ As the sugar beet campaign begins the factory management allows the harvest of enough beets per day to just meet the factory capacity. The date of unrestricted deliveries is established approximately mid-October after which the grower can deliver as many beets as he possibly can in a given day.

12/ Personal conversation, Chief Agriculturist, Holly Sugar Company, Hardin, Montana.

13/ Silin, Technology of Beet Sugar Production and Refining, op. cit., p. 43.

reported that beets were stored for 165 days during a 205-day sugar campaign at the Sal'Kov Sugar Factory with minimum losses of sugar. 14/

Freezing sugar beets represents an alternative to longer storage periods in Montana. The freezing process requires that sugar beets be subjected to temperatures below -7 degrees Centigrade (19 degrees Fahrenheit) to stop respiration and freeze the sugar juices within the beet. Beets must remain frozen until they are delivered for slicing if the amount of recoverable sugar is to be maximized. Sugar beets that have been frozen and allowed to thaw before processing are subject to severe sugar losses. Thawing begins at -5 degrees Centigrade or 23 degrees Fahrenheit.

Freezing sugar beets in certain areas of Russia was accomplished by allowing the beet to be exposed to wind and low temperatures indigenous to the northern latitude environments. Once the beets were frozen solid, they were covered and stored until processing. 15/

Storage of sugar beets at factory sites in Hardin, Sidney, and Billings is done during the months of November through February. If in November or even December, after the beets are piled they could be subjected to temperatures of 5 degrees Fahrenheit to -13 degrees Fahrenheit for 10 to 15 days the beets could be frozen. 16/ Once the piled

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14/ Ibid, p. 39.

15/ Ibid, pp. 36-43.

16/ The process of freezing sugar beets in the pile requires an elaborate system of air ducts and ventilation tubes placed in the beet pile.

beets are frozen they should be covered with matting, snow, and straw. The thickness of the beet pile covering is dependent upon the length of time beets are to be held in storage.

Daily temperature data observed from Billings, Hardin, and Sidney suggest that freezing beets for future processing by using the natural environment (wind and temperature) would at best be a high risk venture. Over the last five years, considering daily high temperatures for November and December, the Sidney area could make use of natural winter temperatures and wind to freeze sugar beets. Hardin and Billings seldom reported more than two days in succession having temperatures below 5 degrees Fahrenheit (Table LXIV). If beet piles could be covered in the daytime and subjected to cold temperatures during the night it is likely that the freezing process via the natural environment could occur at Sidney and Hardin after the middle of November. Temperatures at night are not consistently low enough at the Billings plant to warrant beet freezing by the environmental temperatures. An alternative to freezing beets by temperatures, is to freeze them by cold air compressor-blowers. A system of ducts, ventilators, and fiberglass pile insulators could be adapted to a cold air blower system. The economic feasibility of such a system is unknown at this time. Additional research in forced air sugar beet freezing may be warranted. 17/

17/ Currently, the Great Western Sugar Company management at Billings is experimenting with different methods of preserving beets in piles. The results of the experiments are not available at this time.

TABLE LXIV. NOVEMBER AND DECEMBER TEMPERATURE DATA RECORDED NEAR BEET SUGAR FACTORY AND SUGAR BEET STORAGE SITES IN MONTANA, 1964-1967. a/

	Billings b/				Hardin				Sidney			
	1964	1965	1966	1967	1964	1965	1966	1967	1964	1965	1966	1967
Average daily high temperature												
November	46.8	54.1	48.0	48.9	42.6	50.2	42.7	47.2	36.7	40.0	35.6	41.6
December	32.0	43.5	39.7	36.0	25.4	40.7	32.1	34.5	12.6	34.4	29.6	26.8
Temperature Range												
November	68-11	74-30	66-17	66-31	68-10	78-24	57-15	65-25	65-1	70-12	47-8	57-19
December	42-(-11)	63-14	54-17	60-11	50-(-17)	60-7	53-9	56-4	34-(-16)	59-0	52-4	50-0
Number of days in succession where reported daily high was below 6 degrees Fahrenheit												
November	0	0	0	0	0	0	0	0	2	0	0	0
December	2	0	0	0	2	0	0	1	8	1	1	2

a/ United States Department of Commerce, Climatological Data, Montana, Environmental Science Services Administration, Weather Bureau, Washington, D. C., 1964-1967.

b/ Temperatures recorded at Billings Water Plant.

The other way to preserve sugar content in beets in storage is through dehydration. Dehydration kills the beet cells by drawing water away from the root. Sugar loss through spoilage is eliminated because microorganisms cannot adequately function in a waterless environment. This process can be carried out two ways--artificial dehydration and sun drying. The latter method appears unreasonable in Montana because of the lack of sufficient sun heat and temperatures during the harvest and processing season to fully dehydrate the beets.

The dehydration weight of a beet is approximately one-fourth that of the mature living root. The economic implications of dehydration are (1) reduced transporting costs due to less weight, (2) increased revenue due to low sugar losses, and (3) increased costs due to the dehydration process.

Dehydration of sugar beets to increase storability of the root with low sugar loss was carried out by the Russians as early as 1930. 18/ Problems were encountered that forced the abandonment of the process. Among these problems were (1) excessive fuel consumption (nearly twice as much as the processing requirements); (2) excessive power consumption, (220 h.p. per 100 tons of beets); and (3) low production capacity of the dehydration units. Given the present state of electronic technology, the use of portable dehydration units could be incorporated in the Montana

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18/ Silin, op. cit., pp. 42-43.

beet sugar industry, however, additional research is necessary to determine the economic feasibility of such an operation.

In summary, freezing sugar beets in Montana by using natural winter temperatures appears to be a high risk operation primarily due to unpredictable weather and inadequate storage insulation technology. However, artificial freezing may be a feasible alternative. Also, the dehydration process is a likely method or preserving beets in storage, but more research should be done on both methods to determine the economic benefits and costs of such operations.

Additional Factories:

Another way to enlarge the sugar refining capacity in Montana is to add additional factories to the existing structure of the industry. There are a number of factors that influence the location of a sugar factory. Among these factors are; (1) sugar beet supply areas in relation to plant location; (2) total sugar beet supply; (3) location of the plant in relation to primary resources; (4) location of plant to wholesale sugar markets and; (5) the availability and cost of transportation facilities. 19/

19/ W. H. Dean, Jr., The Theory of Geographic Location of Economic Activities, Edwards Brothers, Inc., Ann Arbor, Michigan, 1938, p. 1. Johann H. Von Thunen developed a theory that undertook to determine the kind of agriculture production that should be carried on at various places, He used a system of concentric circles and priorities to determine what products would be produced at different distances from the consuming and storage centers. See Roland R. Renne, Land Economics, New York: Harper and Brothers Publishers, 1947, pp. 170-175, for a discussion of Von Thunen Theory of Location.

Among those resources that are essential for a new sugar refinery location in Montana are sugar beet supplies, water, rail transportation, a and sufficient land for the disposal of factory wastes. Railroad facilities, water supplies, and land seem to be in sufficient quantity to meet the minimum requirement of a sugar refinery.

One guideline suggested by sugar company officials in establishing new factory locations is the need for approximately 30,000 acres of sugar beets. 20/ The results of the regional supply response model (District 3 North and West Central Region, Model II) indicate that in 1980, 19,000 acres of sugar beets could be expected in Blaine and Phillips counties. There is, however, a large amount of irrigated acreage in Cascade, Teton, and Pondera counties (153,000 acres) of which part could be adaptable to sugar beets. 21/

It is beyond the scope of this work to determine the feasibility of additional sugar factories in selected locations of Montana. However, because of the 19,000 acre sugar beet supply response for 1980, at the northern beet growing areas in Montana, and because farms in other northern Montana irrigated areas, not considered in the 1980 supply response, may

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20/ 30,000 acres of sugar beets was suggested a number of times as the author spoke with sugar company officials. The newest plants built are of the size (4,000 tons of beets per day plus) and degree of automation that would require nearly 30,000 acres of beets to return sufficient income to cover costs and maintain a "reasonable profit".

21/ Personal correspondence from the United States Department of the Interior, Bureau of Reclamation, Region 6, to Mr. Hugo T. Schellin, Chinook Businessmen's Association, December 31, 1963. Farmers in the irrigated sections of Cascade, Teton, and Pondera counties are reported to have grown sugar beets in 1959, 1951, and 1959 respectively.

respond to beet prices, a sugar factory may be justified. Even though the determination of the economic feasibility of such a sugar refinery in the northern portion of the state is left to others, hypothetical cost and returns data for three plant sizes suggest that an adequate return on investment could be expected.

Three hypothetical beet sugar factories representing capacities of 1,500, 3,000, and 4,500 tons of sugar beets sliced per 24 hour day have been specified. The number of sugar beet acres serviced by each plant, the sugar beet yields per acre and the percentage of sugar was assumed to be representative of actual conditions. Sugar beet yields were set at 16 tons per acre and sugar content at 15 percent of which 80 percent is recovered by each factory. The wholesale price of sugar is $9.00 per 100 weight. Beet pulp pellets and molasses are each $34.00 per ton. Sugar beet payment to growers were based on $16.00 per ton. The average investment per factory (1,500, 3,000, 4,500 tons a day) were set at 12, 15, and 18 million dollars respectively. 22/

The costs and returns for three separate sugar refineries are reported in Tables LXV, LXVI, and LXVII. Under the conditions specified, the rate of return on the average investment was greatest in the

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22/ Reports from sugar company officials suggest that the cost of building a 1,500 and 3,000 ton-a-day factory would be 12 and 15 million dollars respectively. The larger plant (4,500 tons per day) would cost nearly 24 million dollars.

TABLE LXV. COST AND RETURNS OF A HYPOTHETICAL SUGAR REFINING FACTORY, CAPACITY, 1,500 TONS OF SUGAR BEETS SLICED PER DAY, 1968. a/

INCOME:		
SUGAR SALES (PRICE PER CWT. $9.00) a/		$5,184,000.00
PELLETED PULP SALES (PRICE PER TON $34.00)		408,000.00
BULK MOLASSES SALES (PRICE PER TON $34.00)		326,400.00
		$5,918,400.00
EXPENSES:	COST/CWT. REF. SUGAR	
YARD EXPENSE	$ .01	$ 5,760.00
SUPERVISION	.14	80,640.00
LABORATORY	.07	40,320.00
BEET SHED LABOR	.04	23,040.00
FACTORY LABOR	.50	288,000.00
CHEMICAL	.06	34,560.00
COKE	.10	57,600.00
LIMEROCK	.21	120,960.00
WATER	.01	5,760.00
KNIVES	.01	5,760.00
FILTERS	.03	17,280.00
FUEL AND POWER (SUGAR)	.26	149,760.00
FUEL (PULP DRYING)	.20	115,200.00
MAINTENANCE	.41	236,160.00
OTHER	.02	11,520.00
SUGAR PAYMENTS AT $16.00 PER TON		3,840,000.00
TAXES (PROPERTY)		130,000.00
TOTAL EXPENSES		$5,162,320.00
NEW INCOME (BEFORE INCOME TAX, DEPRECIATION AND INTEREST)		756,080.00
DEPRECIATION		220,000.00
NET INCOME (BEFORE INCOME TAX AND INTEREST)		536,080.00
INVESTMENT, $12,000,000; RATE OF RETURN ON AVERAGE INVESTMENT, 4.5 PERCENT.		

a/ Acres of Beets, 15,000; yield, 16T/acres; total tons, 240,000; sugar percentage, 15; tons of sugar, 36,000; recoverable sugar, 80 percent; tons of recoverable sugar, 28,800; recoverable sugar (cwt.) 576,000.

TABLE LXVI. COSTS AND RETURNS OF A HYPOTHETICAL SUGAR REFINING FACTORY, CAPACITY, 3,000 TONS OF SUGAR BEETS SLICED PER DAY, 1968.

INCOME:		
SUGAR SALES (PRICE PER CWT. $9.00) a/		$6,912,000.00
PELLETED PULP SALES (PRICE PER TON $34.00)		572,000.00
BULK MOLASSES SALES (PRICE PER TON $34.00)		460,800.00
TOTAL INCOME FROM SALES		$7,944,800.00
EXPENSES:	COST/CWT. REF. SUGAR	
YARD EXPENSE	$ .01	$ 7,680.00
SUPERVISION	.10	76,800.00
LABORATORY	.05	38,400.00
BEET SHED LABOR	.06	46,080.00
FACTORY LABOR	.34	261,120.00
CHEMICAL	.05	38,400.00
COKE	.06	46,080.00
LIMEROCK	.14	107,520.00
WATER	.01	7,680.00
KNIVES	.02	15,360.00
FILTERS	.01	7,680.00
FUEL AND POWER (SUGAR)	.28	215,040.00
FUEL (PULP DRYING)	.20	153,600.00
MAINTENANCE	.38	291,840.00
OTHER	.02	15,360.00
SUGAR PAYMENTS AT $16.00 PER TON		5,120,000.00
TAXES (PROPERTY)		175,000.00
TOTAL EXPENSES		$6,623,640.00
NET INCOME (BEFORE INCOME TAX, DEPRECIATION AND INTEREST)		$1,321,160.00
DEPRECIATION		500,000.00
NET INCOME (BEFORE INCOME TAX AND INTEREST)		821,160.00
INVESTMENT, $15,000,000; RATE OF RETURN ON AVERAGE INVESTMENT, 5.5 PERCENT.		

a/ Acres of beets, 20,000; yield, 16; total tons, 320,000; sugar precentage, 15; tons of sugar, 48,000; recoverable sugar, 80 percent; tons of recoverable sugar, 38,400; recoverable sugar (cwt.) 768,000.

TABLE LXVII. COST AND RETURNS OF A HYPOTHETICAL SUGAR REFINING FACTORY, CAPACITY, 4,500 TONS OF SUGAR BEETS SLICED PER DAY, 1968.

INCOME:		
SUGAR SALES (PRICE PER CWT. $9.00) a/		$10,368,000.00
PELLETED PULP SALES (PRICE PER TON $34.00)		816,000.00
BULK MOLASSES SALES (PRICE PER TON $34.00)		652,000.00
TOTAL INCOME FROM SALES		$11,836,000.00
EXPENSES:	COST/CWT. REF. SUGAR	
YARD EXPENSE	$ .02	$ 23,040.00
SUPERVISION	.14	161,280.00
LABORATORY	.08	92,160.00
BEET SHED LABOR	.04	46,080.00
FACTORY LABOR	.51	472,320.00
CHEMICAL	.08	92,160.00
COKE	.05	57,600.00
LIMEROCK	.10	115,200.00
WATER	.01	11,520.00
KNIVES	.02	23,040.00
FILTERS	.02	23,040.00
FUEL AND POWER (SUGAR)	.24	276,480.00
FUEL (PULP DRYING)	.20	230,400.00
MAINTENANCE	.30	322,560.00
OTHER	.02	23,040.00
SUGAR PAYMENTS AT $16.00 PER TON		7,680,000.00
TAXES (PROPERTY)		200,000.00
TOTAL EXPENSES		$9,849,920.00
NET INCOME (BEFORE INCOME TAX, DEPRECIATION AND INTEREST)		1,986,080.00
DEPRECIATION		650,000.00
NET INCOME (BEFORE INCOME TAX AND INTEREST		1,336,080.00
INVESTMENT, $18,000,000; RATE OF RETURN ON AVERAGE INVESTMENT, 7.4 PERCENT.		

a/ Acres of beets, 30,000; yield 16T/acres; total tons, 480,000; sugar percentage, 15; tons of sugar, 72,000; recoverable sugar, 80 percent; tons of recoverable sugar, 57,600; recoverable sugar (cwt.) 1,152,000.

largest factory (7.4 percent). 23/ The smallest plant showed the smallest rate of return on average investment (4.5 percent).

The estimated cost of producing 100 pounds of sugar varies among each factory. The smallest plant produced sugar at $2.07 per 100 weight, while the largest plant produced sugar at $1.71 per 100 weight. Economies of scale do exist as the 4,500 ton a day plant produced sugar at 36 cents per 100 weight below the smallest plant and .02 cents lower than the middle sized plant. All factories have adequate returns to their average investments.

Montana Sugar Refinery Expansion:

The Montana sugar refining capacity in 1966 measured in tons of sugar beets sliced per 24 hour day was 8,000 tons. At this time, the sugar beet slicing capacity has increased to nearly 8,400 tons per day. Over the years a number of changes have been made in the three existing refineries to increase their daily capacities (Table LXVIII).

According to sugar company management it is expected that the capacity to slice sugar beets will be nearly 10,500 tons daily by 1970. It is expected that by 1975 sugar refineries in Montana will slice 11,500 tons per day. It is not unreasonable to expect the sugar beet

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23/ Assuming a $24 million cost the return on investment would be 5.6 percent.

TABLE LXVII. CHANGES MADE IN THE INTERNAL STRUCTURE OF THREE MONTANA BEET SUGAR PROCESSING FACTORIES, 1906-1968.

Holly Company, Hardin	Holly Company, Sidney	Great Western, Billings
Erected 1937 Capacity 1800 T/D Steffen - New	Moved to Sidney 1925 Capacity 1800 T/D Steffen - Relocated	Erected, 1906 Capacity, 1000 T/D Steffen - New
	Sugar Processing Equipment Changes	
First carbonation	Improved beet handling equipment	New main engine
Improved beet handling equipment	Continuous diffuser	New boilers
Beet pulp drying equipment	New first carbonation	New water line
Additional electric power	Additional first and second carbonation filters	New pans, granulators, and centrifugals
	Additional evaporators	Additional pulp storage
	Additional vacuum pans	New pulp drying equipment
	New crystallizers	New first carbonation station, rotary filters, & centrifugals
	New white centrifugals	Additional bulk sugar bins
	New high raw centrifugals	New boilers
	New drying and cooling equipment	New second carbonation system, sugar storage
	Additional boilers	Lime storage, lime handling equipment
	New electrical generators	Additional second carbonation facilities
	Additional bulk sugar storage bins	New packaging machine
	New pulp drying equipment	Improved water system
		New beet slicers
		Additional bag machines
		New sugar pulverizer
	1967-68 Sugar Refining Capacity	
1900 T/D	2500 T/D	4000 T/D

slicing capacity in Montana refineries to be near 13,500 tons per day in 1980. In order to reach these future capacities a number of changes will be made in the three factories (Table LXIX).

If sugar beet slicing capacity of 13,500 tons a day is reached in 1980, it will be sufficient to handle the estimated sugar beet supply. At $17.50 per ton, it has been estimated that 127,000 acres of beets should be produced. An average yield of 17 tons per acre would result in 2,142,000 tons of beets. With a 13,500 tons a day slicing capacity, 159 processing days would be required to process them. This represents 34 more days than current production requires.

The additional 34 days over current refinery operations of 125 would require that some sugar beets be held in storage from the middle part of November until mid-March or 120 days. This is not an unreasonable length of storage time, but one would expect some sugar losses through respiration. Again, two alternatives are potentially available to reduce sugar losses caused by longer storage requirements. They are (1) improved storage technology (as previously discussed) and (2) the development of "thick" juice storage facilities.

Increased Capacity--Thick Juice Storage:

The internal structure of the plant would be modified to increase thick juice storage. The slicing, diffusion, purification, and evaporation facilities must have a greater daily capacity than the crystallization, centrifuging, Steffen process, and packaging equipment. In a given day

TABLE LXIX. PLANNED CHANGES TO BE MADE IN THE INTERNAL STRUCTURE OF THREE MONTANA BEET SUGAR PROCESSING FACTORIES, 1969-1980.

	Holly Company, Hardin	Holly Company, Sidney	Great Western, Billings
1967-68 capacity	1900 T/D	2500 T/D	4000 T/D
Expected Processing Machine Modification	Slow Diffuser Automatic centrifugals Automatic carbonation	New diffuser Automatic centrifugals New boilers New power system gas heating New pulp drying machinery New beet unloading facilities on railroad spur New lime kiln New carbonation	Not available, however, indications are that changes will be made to increase capacity.
1970 capacity	2100 T/D	4400 T/D	4400 T/D
1975 capacity	2700 T/D	4400 T/D	4400 T/D
1980 capacity	3000 T/D	5000 T/D	5000 T/D

more thick juice would be produced than could be crystallized, but additional vats or tanks could be installed to handle the excess which could be crystallized at a later date.

The Holly Sugar Company has developed thick juice storage techniques. Their plant at Hereford, Texas, contructed in 1964, has a beet slicing capacity of 6,500 tons per day. However, only 4,000 tons of sugar beets could possibly be handled by the total factory facilities in a given day. Thick juice from 2,500 tons of beets per day is stored for future processing.

There appears to be four advantages to delayed processing:

(1) If the slicing, diffusion, purification, and/or evaporation systems were to temporarily fail, thereby eliminating the supply of thick juices for crystallization, sugar processing could continue by utilizing the stored thick juices;

(2) Likewise, if the crystallization, centrifugals or packaging were to temporarily break down, slicing, diffusion, purifying, and evaporation could continue by storing the thick juice produced until repairs could be made.

(3) The utilization of the factory would be increased, i.e., the number of days the factory operated would be increased by drawing from thick juice supplies after harvested beets have all been sliced.

(4) By increasing the capacity of slicing, diffusion, purification, and evaporation facilities, the time sugar beets are held in storage is minimized.

CHAPTER X

SUMMARY AND CONCLUSIONS

Summary

The sugar beet and sugar cane industry in the United States produces approximately 40 percent of domestic annual consumption. Sixty percent of the United States sugar supplies are imported from Hawaii, Puerto Rico, the Virgin Islands, and 30 other areas. United States sugar consumers (household and industry) could find themselves in short supply if off-mainland and foreign sugar supplies were to be restricted from the United States domestic market for one reason or another.

A number of factors could be responsible for restricting foreign sugar from the domestic markets. Among these factors are foreign crop failures, changes in tariff and trade agreements, disagreements with exporting countries, and modifications in domestic sugar policy. Other factors that could influence the supply of sugar in the United States are changes in beet production, sugar manufacturing technology, and the economic relationship of sugar beets to other competing crops.

The Montana sugar industry accounts for 6.4 percent of domestic sugar supplies. Any changes in the world or domestic marketing channels that may affect the United States sugar industry will also influence the Montana industry.

The problem of this research was to estimate potential Montana sugar supplies at alternative sugar beet prices for 1980. Consideration was given to sugar beet production as well as beet sugar manufacturing.

Five sugar beet producing regions were specified in Montana as the primary production areas for 1980. Three discontinuous sugar beet supply estimates were made for each of three regions. The estimates were generated by using variable price linear programming. Methodologically, two sugar beet supply responses were made by using the defined production regions as the responding unit. In contrast the third supply estimate was made by using a set of typical farms as the responding unit. Two additional regions were programmed for the purpose of estimating regional but not typical farm sugar beet supply response.

An examination of the sugar processing industry was made. Four means of increasing the sugar processing capacity of Montana were discussed: (1) increased sugar beet storage time, (2) new factories, (3) additions to existing refineries, and (4) thick juice storage.

Sugar Beet Production

The potential for farmers in Montana to produce sugar beets depends on a number of factors. Among these factors are the availability and cost of irrigated land, labor, capital, and water. Other variables that effect potential sugar beet production are governmental controls, factory capacity, farmer preferences, sugar beet prices relative to competing crops and the weather. Ideally, all of these factors should be taken into account simultaneously in order to estimate an accurate sugar beet supply response for Montana.

In this study, land, labor, and the cost of water were specified as the factors restricting the production of sugar beets. The availability of some types of labor and all capital were recognized as restrictions to sugar beet production, but were assumed to be unlimited for the purpose of this research. Governmental controls were not assumed to be in effect in 1980. It was assumed that normal weather patterns would exist in the defined sugar beet producing regions of Montana in 1980. Grower preferences for specific crop production was largely ignored even though in one model an attempt was made to specify rotation patterns and uses in terms of observed management practices.

The analysis of five sugar beet producing regions in Montana using variable price programming suggest that potatoes are more competitive for scarce productive resources than sugar beets. This conclusion is reached based on projected prices for irrigated crops and projected resource costs. Those crop rotations consisting in part of potatoes were consistently selected by the model for the highest quality irrigated land in all regions studied at sugar beet prices ranging from $14.00 per ton to $18.00 per ton. Only those rotation that consisted of more than one year of sugar beets and those having a combination of sugar beets and potatoes were as competitive for resources as potato rotations at sugar beet prices below $18.00 per ton.

If the projected number of available farm family labor working hours is realized and if seasonal migrant labor supplies remain, for all purposes unlimited, it is reasonable to expect sugar beet production to expand beyond the current capacity of the beet sugar manufacturing facilities in Montana at $17.50 per ton. However, two unknowns, government production controls, and factory contract assignments, could limit beet production to the existing factory capacity of 8,400 tons per day at that price.

There are three sugar beet producing regions in Montana that are located in excess of 200 miles from sugar refining facilities. Based on the regional analysis there would be no sugar beet production in Ravalli County (350 miles from a factory) in 1980 given that potatoes maintain their competitive price position. One need not include transportation costs to see that the former American Crystal Factory District is a marginal sugar beet producing area. Sugar beet production in the Townsend Valley (200 miles from a factory) is stimulated by sugar beet prices in excess of $20.00 per ton. Adding shipping charges of $2.00 per ton may be further evidence that sugar beets are not competitive at projected prices. The farmers in the northern sugar beet district of Regional Farm III, 220 miles from a sugar refining factory, could produce a sufficient amount of beets at $17.50 per ton to merit further considerations of a processing facility. Programmed results indicate that at equilibrium prices sugar beets would be grown on the highest quality land. Also, it is noted that the northern area does not have a serious competitor to the sugar beets crop.

Sugar Beet Processing

There are three beet sugar refining facilities in Montana. The processing of sugar beets requires an extensive capital investment (refinery) that is operated less than 130, 24 hour days. In the off season, a maintenance,crew, administrative personnel, and agricultural specialists are required to be at the factory to render assistance to sugar beet growers and maintain the factory. The full burden of plant overhead is met only when the factory is operated near full capacity. Economic theory suggests that plants operating at less than optimum size at less than an optimum rate may find costs depleting essential profit margins. For example, the American Crystal Sugar Company discontinued doing business at Missoula, Montana, in 1966 because sugar beet supplies were not large enough to operate the relatively small factory at full capacity for more than 60 days.

Considering the combined size of the existing beet sugar refineries in Montana and utilizing the most conservative sugar beet production estimate for 1980, at $17.50 per ton (127,000 acres of 2,159,000 tons at 17 tons per acre) Montana processing capacity is not large enough to process projected sugar beet supplies in 125 days. Beet storage problems restrict factory operation much beyond 125 days.

There are two economic considerations apparent in altering the capacity of the Montana beet sugar industry. The first economic consideration is to increase the industry capacity by more fully utilizing existing factories. The alternatives appear to warrant consideration of: (1) increasing the time sugar beets are held in storage and (2) developing storage facilities for thick juice storage. Both of these alternatives even though potentially possible will require additional study before a definite statement can be made concerning their economic feasibility. The second economic consideration would be to increase the size of existing facilities by (1) expanding the internal structure of existing factories or (2) add a new refinery to the Montana sugar market structure. Expanding the internal structure of plant facilities will occur in Montana by 1980 according to sugar company officials. It is expected that daily slicing capacity will increase from 8,400 tons per day to 13,500 tons per day by 1980 (including two factories in excess of 4,000 tons per day). Cost and returns data developed suggest that larger plant sizes (3,000 and 4,500 tons per day) can be operated profitably in Montana. The expansion of the internal plant mechanism will most likely follow along the patterns required by the lime extraction process rather than the ionization process.

New plant construction is not recommended for the regions studied except in Region III, District 3 (Northern Montana). A cursory examination reveals that a sufficient amount of high quality land and water are available. Transportation facilities (road and rail systems) appear adequate for moving resources to plant locations and final products to markets exogeneous to Montana.

In the opinion of the author, an economic feasibility study concerning the establishment of a sugar refining facility in some location in Phillips, Blaine, Hill, Teton, or Pondera counties is justified based on the estimated sugar beet supply response in the district for 1980 at beet prices near $17.50 per ton.

Methodological Considerations

Implied in the literature concerning the alternative methods of estimating the supply of a given commodity, is the idea that a supply estimate based on a region as the responding unit is inferior to similar estimates derived from representative farms. 1/ This conclusion may not be fully warranted. Therefore, the advantages and disadvantages of a regional and typical farm supply response model are analyzed, based on the results of this study.

In this study selected regions were subdivided into districts. The resources of each district are assumed to be homogenous. By summing the district resource levels, regional resource limits are established. In using benchmark farm models, resources are assumed to be homogenous among farms specified as typical.

Both regional and typical farm supply response models require budget data to quantify the objective function (alternative activities). In the case of a regional model, data reflecting the average farm in a district serves as the cost and return criteria in developing net revenue coefficients. The representative farm model requires specific data about representative farms. A major disadvantage with the regional analysis is the average farm concept. In averaging costs and resource requirements, Hartley concluded, that serious aggregation bias might

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1/ Earl O. Heady, et. al., Agricultural Supply Functions, op. cit., p. 18

exist at the extreme ends of the price range considered. 2/ Averaging over a wide spectrum of farm sizes and types in either a regional or typical farm supply response model is undesirable.

The research resources that are needed to gather pertinent supply response information may be more efficiently used if a regional model is specified. The assertion is based on (1) aggregated resource levels are gathered easily and at a relative small cost from government agencies and bureaus and (2) farm numbers and sizes do not have to be projected by unrefined techniques. 3/

Typical farm supply response models require that the number of farms by benchmark specifications be projected for the purpose of expanding the individual benchmark farm supply estimates to regional size. Models using the region as a responding unit require no such projections which is advantageous for two reasons: (1) one less operation involved in estimating supply and (2) minimization of a type of specification error. One type of specification error developes when regression and/or Markov Chain Techniques are used to project farm size and numbers.

These techniques may cause specification error because of the assumption that past trends reflect future happenings. However, these techniques do not take into account structural changes that occur over time.

2/ H. O. Hartley, "Total Supply Functions Estimated From Farm Survey", North Central Farm Management Research Committee Paper, March 1962.

3/ Criticism of Markov Chains and regression techniques used for this purpose, see Gerald W. Dean, et. al., "Supply Functions for Cotton in Imperial Valley, California, op. cit., pp. 3-6.

If the end product desired in estimating the supply of a commodity is information about the response of specific farm sizes or types then the representative farm model is the best choice even if other models, in the aggregate, are "better". However, if information concerning the response, collectively of all farmers in the region is desired, for policy considerations, then a regional response model is advantageous. The results of a regional model suggest only what will happen at the regional level. Nothing is porporated about individual farmers within the region.

A number of methods have been devised for the purpose of selecting typical farms. Among these methods are: (1) average resource use, (2) size, (3) most limiting resource, (4) resource ratio use, and (5) type of farm. Problems in using and allocating research time and resources to the selection of a meaningful selection criteria is avoided in regional supply analysis.

In summary it is difficult to say that the estimation of supply can be done more effectively using regional or typical farm models per se. Which model is best depends on the purpose and information desired. If information about individual farm units is needed and research resources are not limited, then typical farm models appear to represent the best alternative. However, if collective data is all that is necessary, then a regional supply estimate may be desirable.

APPENDICES

APPENDIX I

RESEARCH CONCERNING THE SUGAR INDUSTRY IN MONTANA COMPLETED BY THE MONTANA STATE AGRICULTURAL EXPERIMENT STATION, MONTANA STATE UNIVERSITY

Bulletin Number	Title	Date
19	The Sugar Beet in Montana	1898
33	Sugar Beets in Montana, The Crop of 1901	1902
41	Sugar Beets, The Crop of 1902	1902
52	Sugar Beets	1903
129	Farm Practice in Growing Sugar Beets in the Billings Region of Montana	1919
215	Experiments with Sugar Beets	1928
232	Successful Farming Practices in the Billings Beets Region	1930
237 (Revised)	Irrigating Field Crops in Montana	1955
292	Grow 20-Ton Sugar Beets	1956
389	Life History and Control of the Sugar Beet Webworm	1941
413	Biochemical Studies on the Subar Beet Webworm	1943
419	Diseases of Sugar Beets in Crop Rotations at the Huntley Branch Station, Huntley Montana from 1936 to 1941.	1943
427	Sugar Beet Diseases and Their Control in Montana	1945
491	Physiology of Growth Sugar Accumulation and Mineral Intake of Sugar Beets in Montana	1953
494	Estimated Water Requirements of Crops in Irrigated Areas of Montana	1953

Bulletin Number	Title	Date
525	Sugar Beet Production in Montana	1956
535	Irrigated Crop Rotations	1958
600	Effects on Nitrogen Phosphorus and Manure Fertilization on Irrigated Crops in a Six-Year Rotation	1966

Circular No.	Title	Date
29	Irrigation Practice in Montana	1913
42	Sugar-Beet Webworm	1914
162	The Subar-Beet Webworm in Montana	1941
168	Sugar Substitutes and Their Uses	1942
171, 177, 182 198, 208	Field Crop Varieties in Montana	1943, 44, 45, 52, and 56
183	Sugar Substitutes and Their Uses in Canning and Baking	1945
205	Irrigation of Sugar Beets	1954

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APPENDIX II

COSTS AND RETURNS FOR SELECTED SUGAR BEET GROWERS IN MONTANA INCLUDING COMPETITIVE IRRIGATED CROPS AND LIVESTOCK OPERATIONS

DEPARTMENT OF AGRICULTURAL ECONOMICS, MONTANA STATE UNIVERSITY, BOZEMAN, MONTANA

This work is being done in conjunction with the Montana State Beet Committee, established and appointed by Governor Babcock, and the National Council of Governor's Sugar Beet Committees.

CONFIDENTIAL

Name ______________________ Address ______________________

Farm Location ______________________ Date ______________

INVENTORIES

Land	Acres Owned	Rented	Totals
Irrig. Crop			
Irrig. Past.			
Dry Land			
Grazing			
Total			

Livestock	Numbers Owned	Leased	Total
Beef Cows			
Beef Feeders			
Dairy Cows			
Ewes and Rams			
Lamb Feeders			
Sows			
Poultry			

Irrigated Crops	Acres	1966 Yield	1966 Total Production	Average 5 year Yield
Sugar Beets				
Dry Beans				
Corn-grain				
Corn-silage				
Potatoes				
Alf. Hay				
Other hay				
Barley				
Oats				
Wheat				

What crop rotation is being followed? ✓

______ ______ ______ ______ ______ ______

How long has this rotation been used? ✓ ______________________________

What changes in the rotation plan do you expect in the future? ✓ ______
____
____
____

Family Labor

What percentage of your time do you spend working on the farm ________%
Type of work off farm ____?

How many members of the family work on the farm? ____________________
(List the members and the percentage of time worked on the farm)

Member	% Time on Farm Work	% Crop	% Livestock

What is the nature of your rental agreement? ______________________
____
____
____
____
____
____
____

SEASONAL AND PART-TIME HIRED LABOR

CROP	NOR. WORK DAY (HOURS)	OPER. % TIME	NUM. OF MEN	COST		HOUS-ING COSTS	VALUE OF OTHER BENEFITS	TOTAL COST PER CROP
				PER HOUR	PER ACRE			

FULL TIME HIRED LABOR

Worker	Normal Hours Worked	Cash Salary	Additional Benefits	Value

Housing Value	Total Annual Cost	Percent Time Crop	Percent Time Livestock	Normal Work Day Hours

What is the source of your irrigation water in 1966?__________________

How much water did you use in 1966?__________________

What was the cash payment for this water in 1966?__________________

In addition to this cash payment, did you supply any equipment, materials or labor for work on off-farm irrigation facilities in 1966?__________________

	Amount	Estimated Value
Equipment		
Materials		
Labor		

Estimate water use by crop in 1966.

Crop	# Irrigations	Amount per irrigation/acre	Total water Used/Acre

What method is used for measuring the amount of water?
- a. Delivered to the farm__________________
- b. Used on farm__________________

Did you have adequate water in 1966? ________
- a. If yes, could you have purchased more?__________________
- b. If no, how much more water would you have been willing to purchase at the same price as paid for your other water?__________________

If you were short of water, how do you ration your water to the different crops?__________________

Do you farm any land as dryland which could be irrigated with your present system?______ How much in 1966?__________________

Do you have any drainage problems?__________ What would be required to correct these drainage problems?__________________

____

What method of irrigation do you use?__________________
- a. What is the capital value of your irrigation equipment?____________
- b. What does it cost to maintain this equipment each year?____________
- c. Using your equipment, what did it cost to apply water in 1966?

Hired labor		Family	
Power		Other	

Was 1966 a fairly "normal" year for you with respect to water?

If not, how did it differ from a "normal" year?

INVENTORY CONTINUED

Buildings and Improvements Used in 1966

Unit	Year Built or Purch.	Cost	Useful Life	Salvage Value	Total Annual Maint.	Dep. Value	Specific Unit Use

INVENTORY CONTINUED

All Farm Machinery Inventory in Use, 1966

Unit Make	Size	Model	Year Purch.	Cost	Useful Life	Sal. Value	Annual Repairs	Dep. Val.
Tractors								
Fert. Spr.								
Manure spr.								
Trailers								
Plows								
Disc								
Spike Har.								
Sp. Tine Har.								
Roller								
Leveler								
Float								
Planters								
Thinner								
Cultivators								
Ditcher								
Sprayer								
Irrigation Eq.								
Harvesting Eq.								
Swather								
Rake								
Mower								
Baler								
Stacker								
Beet dig								
Topper								
Combine								
Corn Chop.								
Corn Pick								
Trucks								
Shop tools								
Automobile								
Others								

LABOR INPUTS PER ACRE FOR MEN, MACHINE, TRACTORS AND TRUCKS

(Start with first crop in rotation)

Crop________ Acres_____ Yield per Acre _________ 1966 Value_______ Value of Byproduct_____

Operation	Machine Width	Times Over	Hours per acre or acres per hour (Identify tractor size and type)
Land Preparation			
Fertilizing			
Planting			
Weed and Insect Control			
Thinning			
Cultivation			
Irrigation			
Topping			
Harvesting			
Hauling			

FERTILIZER, MANURE, AND CHEMICAL INPUTS COST PER ACRE FOR ____________ CROP

Kind of Input	Pounds Per Acre	Applied Acres	Cost Per Acre		Cost Application If Hired
Fertilizer					
Totals for Fertilizer			$		
Sprays	Unit Per Acre (Lbs., gal.)			Method & Purpose of Application	
Total			$		
Dusts					
Total			$		
Manure					
Total			$		
Others					
Total			$		

SEEDING RATES AND COST

Crop	Seeding Rate Per Acre	Grade, Variety	Cost of Seed Per Pound	Acres Seeded
Sugar beets				
Alfalfa				
Beans				
Corn				
Wheat				
Barley				
Oats				
Peas				
Grasses				
1.				
2.				
3.				
Potatoes				
Others				

Comments:

APPENDIX III

HISTORY OF THE BEET SUGAR INDUSTRY IN MONTANA

The recovery of sugar from beets took place in Montana on a non-commercial basis in 1898. Many farmers from throughout the State cooperated with experiment station personnel at the Montana College of Agriculture (Montana State University at Bozeman) for the purpose of determining the feasibility of sugar beet production and beet sucrose manufacturing. Early reports indicate that Montana farmers could produce sugar beets of a high enough quality to merit a refining factory. Early experimental data gathered from 58 farmers showed that sugar beets grown with minimum amounts of management yielded 13.41 percent sugar. 1/ During 1901 sugar beet growers in 17 Montana counties reported yields up to 18.79 tons per acre with 15.30 percent sugar content.

Because sugar beet growers in Montana had grown economical beet yields and because the sugar content of Montana sugar beets was adequate, a strong effort was made to secure a beet sugar refinery for Montana. 2/ Traphagen, in his sugar refinery feasibility study, indicated the economic benefits that would accure to a community supporting a beet sugar factory. Requisites for a successul factory included high sugar beet yields, water,

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1/ Traphagen, The Sugar Beet in Montana, No. 19, op. cit., p.76.

2/ F. W. Traphagen, Sugar Beets in Montana, Montana Experiment Station Bulletin No. 33, Agriculture College of Montana, 1901. During 1902 Colorado reported nine sugar factories in operation. Utah had four operating beet sugar refineries and Idaho and Washington had one each.

drainage, and financing. The procedure that businessmen should follow to secure a factory was presented. 3/

The work of Traphagen and others is thought to have been successful in interesting sugar companies in Montana refinery locations. The Great Western Sugar Company constructed a sugar factory at Billings, Montana, in 1906.

The factory, consisting of five buildings of which the main plant would be 82 by 312 feet and five stories high, would have a daily slicing capacity of 1,000 tons of beets. 4/ Sugar beets from 5,500 acres totalling 55,200 tons were processed in the 1906-07 campaign. Sugar was reported to be 18.19 percent of the harvested beet crop.

Even though a number of problems plagued the factory operation in Billings, the Great Western sugar factory grew. By 1910 the Company had purchased a number of farms for experimental purposes and growers in the Huntley irrigation project as well as farmers at Belfry, Montana, were shipping sugar beets to Billings. There were over 15,000 acres of sugar beets harvested in 1911. 5/ Because of the success of the Billings sugar refinery, petitions were made to build new plants in the Clark Fork area (Western Slope) and in the Big Horn Basin of Wyoming. The Clark Fork,

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3/ F. W. Traphagen, Sugar Beets, Montana Experiment Station Bulletin No. 52, Agricultural College of Montana, Bozeman, 1904, pp. 3-12.

4/ M. C. List, et. al., "History of the Billings Factory District of the Great Western Sugar Company", Unpublished manuscript loaned to the author by James Lyon, Great Western Sugar Company.

5/ Ibid. p.

Montana, factory petition failed but the Great Western Sugar Company established a refinery at Missoula, Montana, in 1917.

During this same year (1917), Amalgamated Sugar Company of Ogden, Utah, made plans to erect a sugar factory at Whitehall, Montana. Reports indicate that $200,000 was pledged by the residents of Whitehall to support the factory. Nearly 7,000 acres of sugar beets were contracted for the 1918 Jefferson Valley Sugar Company campaign by growers in Madison and Jefferson Counties. 6/ The factory never went into production because the potential to grow high yield and quality sugar beets was not thoroughly ascertained. The growing season in the Whitehall area was much too short to guarantee the high quality sugar beets desired. 7/ The factory was removed to Utah in 1918.

Prior to 1925 only the Great Western Sugar refinery at Billings had successfully operated. The Great Western factory at Missoula failed and it was moved to Mitchell, Nebraska. Other sugar companies, however, were interested in Montana.

The Holly Sugar corporation moved a sugar refinery from Anaheim, California, to Sidney, Montana, in 1925. The initial slicing capacity of the Sidney plant was 1800 tons of beets per 24-hour day. Another Holly

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6/ *Ibid*. p. 30.

7/ Jefferson Valley News, Vol. 5, No. 15, October 18, 1917, p. 1.

refinery was established at Hardin, Montana, in 1937. The plant had a capacity of 1800 tons of beets per day. 8/

During the 1927 sugar campaign Amalgamated Sugar Company at Cornish, Utah failed. The equipment from the factory was installed in a new factory built by Amalgamated at Missoula, Montana. 9/ There were 20,708 tons of sugar beets processed in 1928 at Missoula by Amalgamated.

The Amalgamated Sugar Company experienced financial difficulties in 1929. The American Beet Sugar Company purchased 96 percent of the common stock of Amalgamated gaining control of the company. The name of the American Beet Sugar Company was eventually changed to American Crystal Sugar Company and in 1936 American Crystal purchased the Amalgamated refinery in Missoula. 10/ The plant was operated through the 1966 sugar campaign. A number of reasons have been hypothesized in explaining the failure of the American Crystal factory. Among these reasons were (1) the lack of sufficient beet tonnage, (2) poor quality beets, (3) dwindling grower-factory relationships, and (4) weather.

The Utah-Idaho sugar company in 1925 moved its Yakima, Washington, factory to Chinook, Montana because of white fly infestations in the

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8/ P. M. Rosenow, Northern Agricultural Manager, Holly Sugar Corporation, Fargo, North Dakota.

9/ J. R. Bachman, Story of the Amalgamated Sugar Company, The Claxton Printers, Ltd.: Caldwell, Idaho, 1962, p. 97.

10/ Ibid., p. 129.

Yakima Valley. 12/ The factory operated until 1952 when it was dismantled and moved to Moses Lake, Washington. It was thought that weather was the major factor in motivating the move. Two successive years of sugar beets frozen in the ground before harvest prevented satisfactory operations.

During the 1967-68 sugar campaign in Montana, three factories were in operation. The Great Western Sugar factory which now process in excess of 4,000 tons per day, and the Holly Sugar Company with refineries at Sidney and Hardin. The combined Montana sugar processing capacity is 8,400 tons of sugar beets sliced per day.

11/ Fred G. Taylor, A Saga of Sugar, Utah-Idaho Sugar Company, Deseret News Press, 1944, pp. 174-176.

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