An Economic Study of the Beet Sugar Industry in Montana

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Introduction

The major purpose of this study is to analyze the production and processing of sugar beets in Montana. Before the problem area of this research is defined, it is imperative to put the Montana beet sugar industry in perspective by taking a brief glimpse at the production of sugar and its influence in international trade. Because sugar is important internationally, any changes in trade or diplomacy can influence domestic supplies.

International sugar production is salient to the United States because 4.4 million tons or 41 percent of domestic consumption is imported (Table 1). The primary sources of foreign sugar are the Philippines, Dominican Republic, Mexico, Brazil and Peru. Therefore, 59 percent, or 6.3 million tons of raw sugar were supplied by domestice and off-mainland cane and sugar beet growers in 1967. Of this 59 percent, 41 percent was produced by the mainland cane and beet industries and the other 18 percent of domestic requirements originated in Hawaii, Puerto Rico, and the Virgin Islands.

The sugar industry in the United States has continued to expand since early attempts to extract sugar from cane and beets. Cane sugar was first refined in Louisiana in 1791. However, it was 1838 before the first beet sugar refinery was established at Northampton, Massachusetts. Between 1960 and 1967, the continental United States sugar industry produced 27 percent of the world sugar supplies in 20 states. Currently, mainland beet sugar production is found in 18 states, while cane sugar production is concentrated in Louisiana and Florida (Table II).

The beet sugar industry of the United States included 60 refineries in 1967. Colorado and California accounted for 22 factories and 35 percent of the refining capacity in the United States.

Montana Beet Sugar Industry

The beet sugar industry is an integral part of the Montana economy. In 1967, sugar beets were planted on 60,000 irrigated acres with a value of production of 13.6 million dollars. Thus sugar beets do not account for a large portion of the income of Montana farm-

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ers, but in the three major beet producing areas the beet enterprise is the primary source of net income. Beets are usually grown in rotation with grains, row crops, and alfalfa. Some farms also have livestock enterprises to take advantage of the by-products of beet production. Also, the three sugar refineries in Montana are significant to local communities where they are located because they provide employment and a market for some Montana products.

TABLE 1: Total sugar quotas and prorations as granted by the United States government for domestic sugar supply 1967.

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

Source: USDA, ASCS, *Sugar Report*, No. 187, Washington, D.C., December, 1967, p. 22.

Sugar beets in Montana are processed by two refining companies, the Holly Sugar Company at Hardin and Sidney and the Great Western United Corporation at Billings. The combined slicing capacity of these three plants is 8,400 tons per day.

Problem

As previously mentioned, the United States has depended on foreign countries and off-mainland sources for approximately 60 percent of domestic sugar supplies.

Major sugar supply problems could arise in the U.S. if relationships with exporting countries falter or are discontinued. The United States experienced a short-lived sugar crises in 1962 after diplomatic and trade relations were discontinued with Cuba. The impact this event had on the domestic sugar industry was a reduction of

TABLE II: Beet sugar production in the United States 1967.

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

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

TABLE III: Sampling percentage, three regions, 1966.

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

three million tons of sugar imported annually from Cuba.[1] Its quota, however, was eventually allocated to other foreign countries as well as the domestic beet and cane sugar industries. Similar disagreements could temporarily impair domestic sugar supplies depending on the response of mainland cane and sugar beet growers. It is feasible for the domestic sugar industry to expand the physical supply to offset foreign sugar supply reductions. However, little is known concerning the economic supply response of beet producers to price variations.

Because the sugar industry in the United States is affected by changes in world sugar prices, a study is 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 Experiment Stations.[2]

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. Therefore, the problem analyzed in this study is the determination of the potential capacity of the Montana sugar beet and refining industry.

Objectives

The two major objectives of this research are as follows:

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

(2) To determine the potential beet sugar manufacturing capacity for the state based on the results obtained on objective one.

Analytical Method

One of the objectives of this research is to estimate the potential acreage of sugar beets in Montana in response to various sugar beet prices. The basic analytical method chosen was linear programming. A linear program was used consisting of an objective function, alternative activities, restriction, and appropriate input-output coefficients that must be specified. Once the mathematical model is specified, the objective is to maximize profits subject to a set of resource constraints. By revising the objective function for various prices of sugar beets, a supply relation for beets is derived holding the prices of all other competing crops constant.

Area Response Model

Several approaches are possible

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[1] *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.

[2] 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.

in estimating supply responses using linear programming. The two most common methods are the representative farm approach and the regional farm approach. Although there are theoretical and technical problems associated with each method, the regional research committee decided on a single regional model so that the state results could be aggregated into a national model.[3]

Area Under Study

Irrigated portions of the state that traditionally have supported sugar beet production can be divided into five areas which supply three sugar factory districts.

The Great Western United Corporation contracts for sugar beets in the mid-Yellowstone Valley, Milk River Valley, Bitteroot Valley, and Townsend Valley. The Holly Sugar Company has two factory districts in Montana. They are located in the extreme lower Yellowstone Valley at Sidney and the Big Horn River Basin at Hardin (Figure 1.)

There are other irrigated areas in the state capable of supporting 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.

[3] For a discussion of the problems involved in the methodology see J. A. Sharples, T. A. Miller, and L. M. Day, "Evaluation of a Firm Model in Estimating Aggregate Supply Response," North Central Regional Bulletin No. 179, January 1968.

Sampling Frame

The population considered in this study consists of farmers supplying sugar beets to refining factories located in Montana. This population includes sugar beet growers in Montana, Wyoming, and North Dakota.

A random sample of about 11 percent of the growers was taken in the three factory districts that represent three regions. Of the 1,124 sugar beet producers 122 were interviewed (Table III).

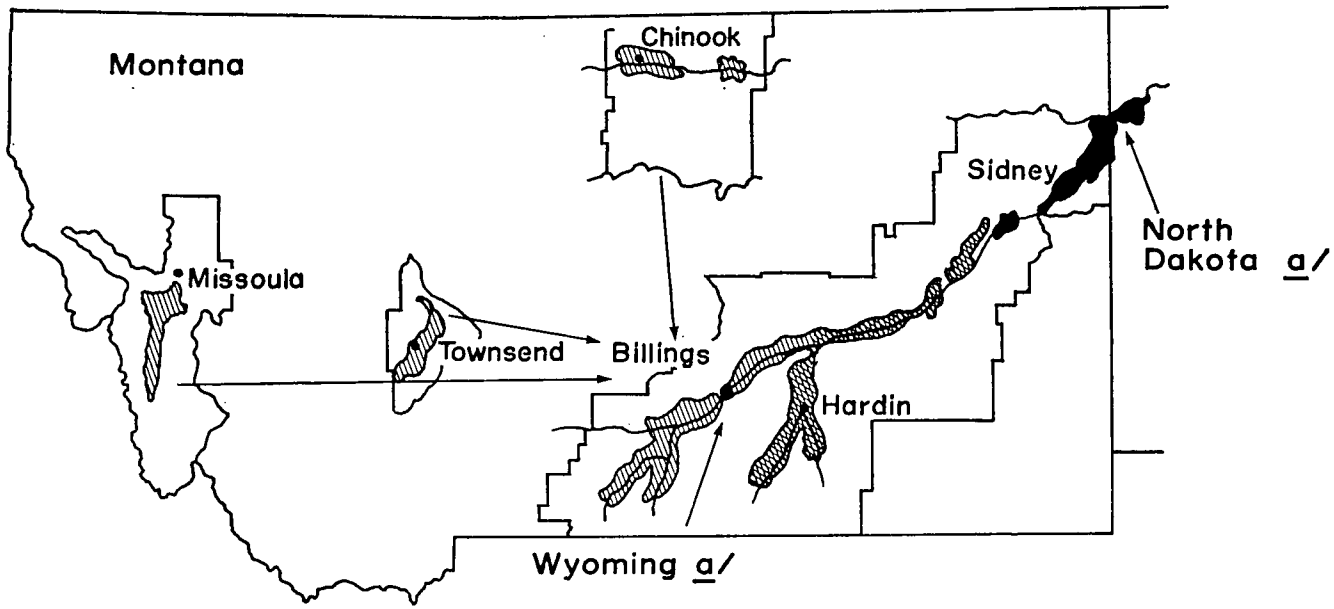
Two other regions were designated. They are the Bitterroot Valley south of Missoula and the Townsend Valley of Broadwater County. A survey was not necessary in these areas because reliable secondary data were available.[4]

Assumptions of the Regional Model

Although the assumptions differ slightly for each of the five regional models, the following general assumptions were made:

1) The standard assumptions of linear programming are applicable to the problem.
2) Sugar beet growers maximize profits.
3) Acreage allotments and controls would be nonexistant.
4) Unlimited processing capacity exists.

[4] Dale M. Stevens, *Costs and Returns for Irrigated Crops in Wyoming*, Agricultural Experiment Station, Bulletin No. 467, University of Wyoming, Laramie, Wyoming, March 1967 and J. Wayne McArthur, "Economic Impact of Beet Production and Refining, Ravalli County, Montana, 1965," Review Draft NRED, ERS, USDA, pp. 10-66.



a/ Arrows indicate sugar beet flow patterns.

Figure 1. Montana Sugar Factory District and Regional Farms, 1966.

5) Irrigation water is in unlimited supply.
6) Capital is also in unlimited supply.

With these general assumptions the various segments of the linear programming model including activities, restrictions and input-output coefficients were developed.

Activities

A number of cropping practices and livestock operations are possible alternatives on irrigated farms in Montana. Among the cropping alternatives are sugar beets, alfalfa hay, corn silage, wheat, oats, beans and barley. Less popular alternatives to sugar beet production include 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 alternative enterprises.

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.

Sugar beet growers in Montana use crop rotations to break the life cycle of the nematode. The proper combination of nematode host and non-host crops is necessary for continued high sugar beet yields.[5] Crop rotations also serve to maintain the soil quality by restoring essential growth elements that have been depleted. Research carried out at the Huntley Agricultural 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.[6]

The profitability of each cropping pattern included in the regional farm supply response models was determined by using the cost data gathered from growers.[7] The variable cost per acre was determined for each crop within the rotations. 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

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[5] Morgan A. Goldin and Edset C. Jorgenson, *The Sugar Beet Nematode and Its Control*, USDA, Leaflet No. 486, January 1961.

[6] 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.

[7] See Gail L. Cramer, and Willard H. Godfrey Jr., *Costs and Returns of Producing Sugar Beets and Other Irrigated Crops in Montana*, Bozeman, Agricultural Experiment Station Bulletin 635, 1969.

the net revenue coefficient for one unit of a given cropping sequence.

To determine a 1980 supply response for sugar beets each activity level and net revenue coefficient was projected to 1980. This was done by projecting the costs of inputs, crop yields, and prices received in 1980.

Restrictions

Individual factors of production such as land, labor, capital, water, and machinery are limited in supply to the individual farm, and therefore, represent restriction levels for sugar beet production. Other limitations that could restrict sugar beet production in Montana are sugar beet quotas, factory contracts, distance from refining facilities, grower knowledge, experience, attitude, and age.

Each of the regions 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 each region.

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 were based on land slope, texture, permeability, drainage, and organic matter.[8] Because it was difficult to assign specific yields to a given soil type, the Soil Conservation Service provided the assistance necessary in breaking down their eight soil classifications into the four classifications used by the Bureau of Reclamation.

The 1966 inventory of irrigated land was determined for each region. The 1980 inventory of sugar beet producing land was ascertained by adding to the 1966 inventory of new irrigation projects to be completed by the Bureau of Reclamation, State Engineers Offices, and private individuals. Thus, a projected 1980 irrigated land inventory capable of supporting sugar beets was established for each region.

Labor, the other major factor limiting the production of sugar beets, consisted of migrant hand labor, local part time labor, and family labor. For the most part, farmers contracting with Great Western United Corporation thinned their sugar beets mechanically. However, Holly Sugar Company growers primarily use hand labor for hoeing weeds and thinning beets. The supply of domestic migrant labor is provided through 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 regions is used mostly in non-beet crops such as hay, grains, and corn silage. According to reports from

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[8] A. A. Klingbiel and P. H. Montgomery, *Land-Capability Classification*, USDA, Soil Conservation Service, Agriculture Handbook No. 210, Washington, D.C., September 1961.

the growers, preharvest work, including irrigation, is carried out by family labor. Some harvest operations require one or two additional men.

Results of the Study

The aggregate 1980 Montana sugar beet supply relation has been estimated using two models. The first model is the regional response model; the second is a regional response model with land use limitations since sugar beets must be grown in rotation to control diseases.

Regional Response Model I

The Montana sugar beet supply for 1980 was formed by horizontally summing the supply response generated from the five production areas (Table IV). At a projected 1980 price of $17.50 per ton it is estimated that 171,481 acres of sugar beets should be planted on approximately 21 percent of the available irrigated land included in the study.[9] These totals can be compared to an average price of $15.87 per ton and an acreage planted of 61,400 acres in 1966.

At the projected 1980 price, the Sidney, Missoula and Townsend areas would not produce any sugar beets; the Hardin areas, 109,248 acres; and the Billings area, 62,233 acres; under the assumptions of the linear programming model.

Even though the supply estimates are biologically feasible in the aggregate, the supply response estimates exceed the biological requirements in the Hardin area.[10] The beet response in the Hardin area would occupy 45 percent of the available land. Even though it is feasible to plant 45 percent of the Hardin acreage to beets for one year, continuous cropping would eventually lower the yield per acre.

Regional Response Model II

The second 1980 aggregate Montana sugar beet supply estimate was made with a model designed to limit each rotation to a maximum of one-fifth of the available land at all prices of sugar beets (Table V). 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 was 43,884 acres less than the response generated at the same price with Model I.

Model I had a lower aggregate response at sugar beet prices below $17.00 than Model II. How-

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[9] Prices received by Montana farmers for crop produced on irrigated land were projected to 1980 as follows: 1962-65 Montana Price ÷ 1962-65 U.S. Price × 1980 projected U.S. Price = 1980 Projected Montana Price.

[10] Sugar beets must be grown in a rotation in most areas of Montana to control nematodes. See Morgan A. Goldin and Edsel C. Jorgenson. *The Sugar Beet Nematode and Its Control*, USDA Leaflet No. 486, January 1961.

ever, 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. Usually, the next best alternative to the potato rotations were crop sequences consisting of sugar beets.

Above $17.00 per ton in Model I, rotations including sugar beets were more competitive, and, therefore, dominated the solutions. Therefore, at any price above $17.00 there are fewer beets than in Model I because potato rotations (now the next best alternative) enter the solutions on the remaining land.

Model II, regional farms with land use limitations, appears to be the most desirable long run estimate of sugar beet production because it allows for disease control and allows for observable cropping patterns.

However, without the land use limitation the following rotations maximized grower profits with sugar beets at $17.50 per ton:

Sidney: 1) potatoes, corn for grain,

TABLE IV: Sugar beet supply response by region for Montana in 1980, Model I analysis.

Price per Ton	Regional Supply Responses					Total Montana Response
	Region I (East Central) Sidney	Region II (South Central) Hardin	Region III (North and West Central) Billings	Region IV (Western) Missoula	Region V (Western) Townsend	
(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		116,896	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

barley; 2) potatoes, beans, corn silage.

Hardin: 1) barley, alfalfa, potatoes, beans; 2) corn silage, wheat, sugar beets, sugar beets.

Billings: 1) oats, alfalfa, alfalfa, potatoes, sugar beets.

Missoula: 1) wheat, alfalfa, alfalfa, alfalfa, corn silage, potatoes; 2) wheat, alfalfa, alfalfa, alfalfa, beans, potatoes.

Townsend: 1) alfalfa, alfalfa, alfalfa, alfalfa, potatoes, potatoes.

Beet Sugar Processing

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

Processing Season

One way that Montana's beet sugar capacity would be expanded is to increase the number of days that the factories operate during the sugar campaign. At the end of 1969 the daily capacity of the sugar industry in Montana was close to 9,000 tons of beets sliced per day.[11]

TABLE V: Sugar beet supply response by region for Montana in 1980, Model II analysis, including land use limits.

Price per Ton	Regional Supply Responses					Total Montana Response
	Region I (East Central) Sidney	Region II (South Central) Hardin	Region III (North and West Central) Billings	Region IV (Western) Missoula	Region V (Western) Townsend	
(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	119,015
16.50	3,488	68,488	44,505	1,818	1,856	120,115
17.00	3,488	69,420	47,215	1,818	1,856	122,797
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	11,722	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	77,581	2,409	13,593	175,519
20.50	6,192	76,763	77,481	3,409	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

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) 66,175 acres of beets could be harvested and processed. The projected 1980 sugar beet supply response is 127,000 acres (Model II) or 60,824 acres (1,034,008 tons) more than the eisting capacity could process in 125 days. Some believe that the extra sugar beet acreage could be harvested and processed by operating the factories for more than 125 days.

However, 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 expected 1969 capacity of 9,000 tons. Adding 114 days to the processing season 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. In the respiration process, sugar stored in the beet is used. Therefore, the 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 sugar content 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 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.[12]

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.[13] It has been estimated that sugar beets will be stored nearly 140 days during the 1968 campaign at Hardin, Mont.[14]

There are alternative processes that may be used to preserve sugar

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[11] Current expansion programs at the beet sugar plants in Montana increased the daily beet slicing capacity from 8,400 to 9,000 tons at the end of 1969.

[12] R. H. Cottrell, *Beet-Sugar Economics*, Claxton Printers, Caldwell, Idaho, 1952, p. 222.

[13] As the sugar beet campaign begins the factory management allows the harvest of enough beets per day to 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.

[14] Personal conversation, Chief Agriculturist, Holly Sugar Company, Hardin, Montana.

beets in storage. Such methods may be feasible at Montana sugar factory sites to increase storability 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.[15] It was 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.[16]

Freezing sugar beets represents an alternative to longer storage periods in Montana. The freezing process requires that sugar beets be subjected to temperature 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.[17]

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.[18] Once the piled 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, only 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 VI). 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

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[15] Silin, *Technology of Beet Sugar Production and refining, op. cit.*, p. 43.

[16] *Ibid.*, p. 39.

[17] *Ibid.*, pp. 36-43.

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

TABLE VI: November and December temperature data recorded near beet sugar factory and sugar beet storage sites in Montana, 1964-1967.

	Billings				Hardin				Sidney			
Average daily high temperature	**1964**	**1965**	**1966**	**1967**	**1964**	**1965**	**1966**	**1967**	**1964**	**1965**	**1966**	**1967**
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	42-(–11)	63–14	54–17	60–11	68–10	78–24	57–15	65–25	65– 1	70–12	48– 8	57–19
December	68–11	74–30	66–17	66–31	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° F												
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

Source: U.S. Department of Commerce, *Climatological Data, Montana,* Environmental Science Services Administration, Weather Bureau, Washington, D.C., 1964-1967.

warrant beet freezing. An alternative to freeing beets by natural methods 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.[19]

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 micro-organisms 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 natural 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.[20] 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 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 insulatioin technology. However, artificial freezing may be a feasible alternative. Also, the dehydration process is a likely method of 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 re-

[19] Currently, the Great Western United Corporation management of Billings is experimenting with different methods of preserving beets in piles. The results of the experiments are not available at this time.

[20] Silin, *op. cit.*, pp. 42-43.

lation 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.[21]

Among those resources that are essential for a new sugar refinery location in Montana are sugar beet supplies, water, rail transportation, 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.[22] The results of the regional supply response model (North and West-Central Region, Model II) indicate that in 1980 about 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 but was not included in this study.[23]

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 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 return data for three plant sizes suggest that an adequate return on investment could be expected.

Three hypothetical beet sugar factories representing slicing capacities of 1,500, 3,000, and 4,500 tons of sugar beets 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

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[21] W. H. Dean, Jr., *The Theory of Geographic Location of Economic Activities*, Edwards Brothers, Inc., Ann Arbor, Michigan, 1938.

[22] Thirty thousand acres of sugar beets was suggested a number of times as the authors 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."

[23] Personal correspondence from the U.S. 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 1939, 1951, and 1959, respectively.

wholesale price of sugar is $9 per hundredweight. Beet pulp pellets and molasses are each $34 per ton. Payments to growers were based on a beet price of $16 per ton. The average investment per factory (1,500, 3,000, 4,500 tons a day) was set at 12, 15, and 24 million dollars, respectively.

The costs and returns for three separate sugar refineries are reported in Tables VII, VIII, and IX. Under the conditions specified, the rate of return on the average in-

TABLE VII: Cost and returns of a hypothetical sugar refining factory, capacity 1,500 tons of sugar beets sliced per day, 1968.[a]

Income:		**Dollars**
Sugar sales (price per cwt. $9)[b]		5,184,000.00
Pelleted pulp sales (price per ton $34)		408,000.00
Bulk molasses sales (price per ton $34)		326,400.00
Total		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 per ton		3,840,00.00
Taxes (property)		130,000.00
Total Expenses		5,162,320.00
Net 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%		

[a] These costs are synthesized, based on data collected from local sugar factories. Investment refers to the cost of building a new plant, not the investment in Montana plants. All cost figures were checked by the central offices of the two sugar companies with facilities in Montana.

[b] Acres of beets, 15,000; yield 16 tons/acre; 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.

vestment was greatest in the largest factory (5.6 percent). 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 hundredweight, while the largest plant produced sugar at $1.71 per hundredweight. Economies of scale do exist as the 4,500-ton a day plant produced sugar at 36 cents per hundredweight below the smallest plant and .02 cents lower than the middle-sized plant.

Expanding Existing Refineries

The Montana sugar refining capacity in 1966 measured in tons of

TABLE VIII: Costs and returns of a hypothetical sugar refining factory, capacity 3,000 tons of sugar beets sliced per day, 1968.[a]

Income:		**Dollars**
Sugar sales (price per cwt. $9)[b]		6,912,000.00
Pelleted pulp sales (price per ton $34)		572,000.00
Bulk molasses sales (price per ton $34)		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 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%

[a] Same as footnote (a) Table VII.

[b] Acres of beets, 20,000; yield, 16 tons/acre; total tons, 320,000; sugar percentage, 15; tons of sugar, 48,000; recoverable sugar, 80 percent; tons of recoverable sugar, 38,400; recoverable sugar (cwt.) 768,000.

sugar beets sliced per 24-hour day was 8,000 tons. Since that time, the capacity of these plants has been increased to nearly 8,400 tons per day. In order to increase slicing capacities a number of changes have been made in the refineries. (Table X).

According to sugar company management it is expected that the combined slicing capacities of Montana refineries will be nearly 10,500 tons daily by 1970. Also, 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 slicing capacity in Montana re-

TABLE IX: Cost and returns of a hypothetical sugar refining factory capacity 4,500 tons of sugar beets sliced per day, 1968.[a]

Income:		**Dollars**
Sugar sales (price per cwt. $9)[a]		10,368,000.00
Pelleted pulp sales (price per ton $34)		816,000.00
Bulk molasses sales (price per ton $34)		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 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 $24,000,000; Rate of return on average investment 5.6%

[a] Same as footnote ([a]) Table VII.

[b] Acres of beets, 30,000; yield, 16 tons/acre; 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.

TABLE X: 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	Moved to Sidney, 1925	Erected 1906
Capacity 1,800 T/day	Capacity 1,800 T/day	Capacity 1,000 T/day
Steffen—New	Steffen—Relocated	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, and 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 packaging machine
	New electrical generators	Additional second carbonation facilities
	Additional bulk sugar storage bins	Improved water system
	New pulp drying equipment	New beet slicers
		Additional bag machines
		New sugar pulverizer
1967-68 Sugar Refining Capacity		
1,900 T/day	2,500 T/day	4,000 T/day

fineries 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 XI).

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-ton a day slicing capacity, 159 days 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. 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.

Thick Juice Storage

The internal structure of the plant could 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 more thick juice could 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, constructed 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 the harvested beets have all been sliced;

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

TABLE XI: 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	**1,900 T/day**	**2,500 T/day**	**4,000 T/day**
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	2,100 T/day	4,400 T/day	4,400 T/day
1975 capacity	2,700 T/day	4,400 T/day	4,400 T/day
1980 capacity	3,000 T/day	5,000 T/day	5,000 T/day

Summary and Conclusions

The sugar beet and sugar cane industry in the continental United States produces approximately 40 percent of domestic annual consumption. Sixty percent of the United States' sugar supplies are imported from off-mainland sources and 30 other countries. United State 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.

At the present time, the Montana sugar industry accounts for about 6 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.

Based on present agricultural cropping patterns five sugar beet producing regions were specified in Montana as the primary production areas for 1980. Two discontinuous sugar beet supply esimates were made for each region. The estimates were generated using linear programming. The two sugar beet supply responses were made using the defined production regions as the responding unit rather than typical farms.

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

Sugar Beet Production

The production potential for Montana sugar beet farmers 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, capital 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, and costs of water 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 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 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 per ton to $18 per ton. Only those rotations consisting 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 per ton.

If the projected number of available farm family labor working hours is realized and if seasonal migrant labor supplies remain 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 existing acreages.

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 assuming that potatoes maintain their competitive price position. One need not include transportation costs to see that the former American Crystal Factory District was 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 per ton. Adding shipping charges of $2 per ton may be further evidence that sugar beets are not competitive at projected prices. The farmers in the northern sugar beet district of Region 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 1980 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 beet crop.

Sugar Beet Processing

There are three beet sugar refining facilities in Montana. The

processing of sugar beets requires an extensive capital investment for a 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 or 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) adding 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 return data developed suggest that larger plant sizes (3,000 to 4,500 tons per day) can be operated profitably in Montana.

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

In the opinion of the authors, 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 projected sugar beet prices.

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