DIVISION OF AGRICULTURAL SCIENCES
UNIVERSITY OF CALIFORNIA

A Simulation Model of Grower-Processor Coordination in the Beet Sugar Industry

by

James N. Niles

and

Ben C. French

CALIFORNIA AGRICULTURAL EXPERIMENT STATION
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS

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by

James A. Niles[1] and Ben C. French[2]

INTRODUCTION

A major factor affecting the efficiency of producing and marketing processed agricultural products is the manner of coordinating grower and processor activities. This involves determining how much to produce, what qualities to produce, where and when to plant, when to harvest, and how to allocate quantities among factories. Decisions made at one level or at one point in time influence the performance of the system at other levels and other points in time. For example, if quantities planted exceed factory capacities, growers may be unable to sell all of their product, or they may have to defer harvesting and so affect the yields and quality of their product and possibly interfere with other farming activities. On the other hand, if the flow of product from farm to factory is irregular, processing costs may be increased because of higher inventory levels, increased waiting time, possible overtime, and changes in product quality. The coordination of the activities is usually made difficult by uncertainties as to weather and biological factors which influence growth rates, yields, and the ability to perform harvest and assembly operations at desired times.

This study develops a model which simulates via computer the operations of a sugar beet production–processing system consisting of a single processor (with four plants) and approximately 1,000 associated growers. The 180,000 acres of beets included in the system (more than half of the California total) is a significant component of the agricultural industry of the state. Similar models could be constructed for other sugar beet systems, and the general analytical framework and quantitative approaches appear applicable to many processing commodities.[3]

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[1] Assistant Professor, Food and Resource Economics Department, University of Florida, Gainesville.

[2] Professor of Agricultural Economics and Agricultural Economist in the Experiment Station and on the Giannini Foundation, University of California, Davis.

[3] If we were attempting to design a model for the entire state, we would, of course, have to take account of interactions among processing firms. Actions and organization which appear optimal for the single system may not be optimal (with respect to the public interest) for the industry as a whole. In practice, an industry–wide optimum may be very difficult to achieve in the absence of any central planning authority.

The study has three main objectives. The first is to formulate an analytical framework for measuring cost and efficiency relationships associated with the scheduling component of producing and processing agricultural commodities. This involves time, quality, and uncertainty dimensions that have been largely neglected or assumed away in traditional theoretical models of production which have focused only on parts of total systems. The second objective is to provide a basis for evaluating the effects of changes in the system on costs and returns to both producers and processors. The model developed serves as a tool for an improved system design and for evaluating the efficiency of the present system. The third objective is to suggest ways in which some tools of management science––particularly computer simulation and linear programming––may be used to formulate improved decision rules and to choose among alternative decision strategies.

The first section of the report presents a brief description of the sugar beet industry of California. With this background, we then describe the specific production–processing system to be studied. This is followed by an explanation of how we formulated the computer model which simulates the economic behavior of this system. We then show how the model may be used to evaluate potential gains (or losses) to growers and processors from changes in decision rules or alterations of the system. The final section reviews the implications of the analysis with respect to the efficiency of the present system and the potential value of further research along these lines.

It is important to note that scheduling and allocation rules which are optimal for the processor conceivably may be less than optimal for individual growers, the degree of divergence depending on the location and environmental factors affecting each grower and the contractual arrangements under which growers are paid for their product. The efficiency of a coordination system thus may vary with one's point of view. The public interest usually is best served by a system which minimizes the combined costs associated with the total production–processing system. Equity considerations may suggest contractual arrangements which compensate producers who would otherwise incur higher costs or reduced returns under an improved total system. In any case, the analysis of any coordination system must consider these potentially diverse interests.[1]

THE CALIFORNIA SUGAR BEET INDUSTRY

Sugar beets are a major California crop. In 1971 it was the tenth leading farm product with an annual contribution of about $126 million to the state's economy [2]. California leads all states in sugar beet production. In the calendar year 1972, 31 percent of the production and 28 percent of the harvested acreage of the United States were in California. The comparable figures for 1968–1972 are shown in Table 1.

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[1] In a complete social welfare analysis, we would also need to consider the effects of alternative systems on other interests such as labor and resource utilization. The impact would appear to be rather minor in this case.

TABLE 1

Harvested Acreage and Production of Sugar Beets
in California and the United States
1968-1972

Harvest year	California					United States		
	Acreage			Production		Acreage		Production
	1,000 acres	percent of U. S. acreage	average tons per acre	1,000 tons	percent of U. S. total	1,000 acres	average tons per acre	1,000 tons
1968	254.2	18.0	23.9	6,081	24.0	1,410.0	18.0	25,363
1969	305.2	20.0	19.8	6,046	21.8	1,540.5	18.0	27,736
1970	320.5	22.7	26.0	8,342	31.6	1,413.3	18.7	26,378
1971	346.5	25.9	23.6	8,165	30.2	1,339.6	20.2	27,044
1972	326.0	24.2	27.5	8,965	31.4	1,345.8	21.2	28,523

Source: U. S. Statistical Reporting Service, Crop Reporting Board, Crop Production, Annual Summaries.

Sugar beets are grown from Imperial County in the south to Tehama County in the north. The leading counties of production are Imperial, Kern, Yolo, San Joaquin, Fresno, Solano, and Monterey. Table 2 shows each county's harvested acreage, percent of totals, tons per acre, percent of sugar, and number of farming units for the 1970 crop.

Cultural Factors

The sugar beet (*Beta Vulgaris L.*) is a biennial plant. In the first year, the beet puts on top growth and then follows with the development of a large taproot where the sugar is accumulated. In the next year, a seed stock shoots up (known as bolting), and the plant may utilize the sugar reserves accumulated in the previous year. Beets are typically harvested prior to the end of the first growing season; but in northern areas of California, beets may be "overwintered" and harvested in the spring, ideally before bolting.

The sugar beet is a cool–season, cold–hardy plant. It grows best in areas where the temperatures are moderate. In the hotter areas of California's interior valleys, the crop is planted in the fall or winter and harvested in the late spring or summer.

Sugar beet production is measured in terms of tons of roots and pounds of sugar per acre. High sugar percentage is favored by cool night temperatures since lower temperatures are conducive to sugar storage by inhibiting its utilization for plant growth. In either warm or cool climates, sugar percentage can be increased by causing the plant to become deficient in nitrogen and, thus, restricting growth.

Beet production is subject to several types of diseases and insect pests which have important influences on yields and may restrict the location and time of planting. Of particular importance are three aphid–borne viruses––Beet Yellows, Beet Western Yellows, and Beet Mosaic. The California Department of Agriculture has estimated losses from these viruses as high as $21 million per year [3].

Efforts to reduce the effects of these viruses have included research to develop resistant varieties, determining best periods to apply insecticides, establishing planting times which reduce the possibility of disease infestation, and establishing beet–free areas to restrict the spread of diseases. Beet–free areas are areas where no beets are in the ground for a period of time. The harvest is completed before the heavy rains force a discontinuance of harvest in the fall (frequently a target date of November 1 is used). This practice eliminates the overwintered beets which serve as a source plant for the Virus Yellows carrying aphids. Beet–free areas are located far enough away from nonbeet–free areas to eliminate migration of the aphid.

Other diseases that are significant are Curly Top Virus and *Cercospora* leaf spot. The Curly Top Virus is spread by an insect vector, the beet leafhopper, *Cirulifer Tenellus*

TABLE 2

California Sugar Beet Production by County, 1970

County	Harvested acreage	Percent of California total		Average tons per acre	Average sugar percent	Number of farming units
		Acreage	Tonnage			
Alameda	1,348.2	.47	.44	23.9	15.51	11
Butte	3,688.6	1.28	1.07	21.4	14.22	21
Colusa	12,823.1	4.45	3.97	22.9	16.16	55
Contra Costa	1,860.8	.65	.66	26.3	15.69	10
Fresno	25,387.0	8.82	7.32	21.3	14.65	79
Glenn	2,361.6	.82	.63	19.8	14.41	13
Imperial	58,877.0	20.45	20.82	26.1	16.59	186
Kern	28,816.3	10.01	9.99	25.6	14.00	140
Kings	8,726.3	3.03	1.87	15.8	14.66	21
Los Angeles	2,117.3	.73	.64	22.4	16.42	5
Madera	1,237.4	.43	.50	29.8	14.35	10
Merced	6,534.4	2.27	2.33	26.4	16.12	34
Monterey	14,764.1	5.13	6.86	34.3	16.28	143
Orange	629.5	.22	.21	24.1	13.96	7
Riverside	3,593.1	1.25	1.38	28.4	13.45	18
Sacramento	5,959.6	2.07	1.95	24.2	15.56	46
San Benito	1,168.0	.41	.44	27.7	15.54	25
San Bernardino	98.5	.03	.04	27.4	13.15	1
San Joaquin	28,291.9	9.83	11.60	30.3	16.08	198
San Luis Obispo	2,245.7	.78	.62	20.4	15.87	18
Santa Barbara	4,141.0	1.44	1.37	24.4	15.63	24
Santa Clara	784.5	.27	.30	28.3	15.84	10
Santa Cruz	168.5	.06	.08	32.9	16.53	5
Solano	21,159.2	7.35	7.53	26.3	16.40	113
Stanislaus	4,048.7	1.41	1.55	28.3	14.61	31
Sutter	4,853.2	1.68	1.72	26.1	15.97	18
Tehama	1,075.8	.37	.36	24.6	13.53	6
Tulare	10,069.7	3.50	3.26	23.9	13.53	80
Ventura	2,255.4	.78	.88	28.8	15.69	31
Yolo	28,827.7	10.01	9.61	24.6	15.96	115
TOTAL	287,912.1	100.00	100.00	25.3	15.65	1,474

Source: U. S. Agricultural Stabilization and Conservation Service, California, 1971 Annual Report, pp. 53-55.

(Baker). This disease nearly wiped out the industry in the 1920's before resistant varieties and a control spray program were adopted. The *Cercospora* leaf spot is caused by the fungus, *Cercospora Beticola,* which attacks the leaves of the beet.

Nematodes constitute the principal pest of the beets. The nematodes are small worms which attack the beetroot and stunt the growth. To reduce the danger of nematode infestations, a rotational program is required. A crop of sugar beets generally should not follow another crop of sugar beets. Since sugar beets are a deep–rooted crop often penetrating to 6 feet, it is a good crop to be used in a rotational program with shallow–rooted crops, benefiting from the previous crop's unutilized fertilizer.

Beet yields increase as the time interval from planting to harvesting increases. Sugar percent is affected by the time of harvest, principally, through the degree of nitrogen deficiency and temperature immediately prior to harvest.

In some areas of California, the time of planting may be restricted by the weather, by efforts to plant before or after certain dates to avoid disease infestations, and by the previous crop still being in the ground. To reduce the occurrence of Yellow Virus in the Delta and the Northern Central Valley areas, planting may be delayed until late spring after the peak of the aphid flights. In the Southern Central Valley, winter planting is encouraged to reduce Curly Top infestations, and late planting is discouraged to avoid nematode infestations.

Harvest and Assembly Operations

All sugar beets are harvested mechanically by diggers which convey the topped beets directly into trucks in the field. The beets are then either transported directly to a factory or, more commonly, to a country receiving station. At the receiving station the truck passes over a scale, and the weight of the truck and beets is determined. The beets are then dumped, screened, and conveyed into railcars, transports (trucks contracted by the processor to move the beets to the factory), or directly into storage if received at the factory. Dirt, small beets, and trash are eliminated by screens and rollers. This waste is collected and transported away by the processor.[1] The empty truck is then reweighed. The difference between the initial weight of the truck loaded with beets and the empty truck weight is the field or gross weight. The dirty or first net weight is this weight minus the quantity of waste removed.

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[1] The grower reimburses the processor for the expense of hauling this wastage away. This is called the dirt haul charge.