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THE ECONOMICS OF GROWING SUGAR BEET ON FARMS IN SOUTH OTAGO

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C O N T E N T S

CHAPTER 1

INTRODUCTION

In recent years farmers and agricultural scientists have become increasingly interested in the possibilities of diversifying New Zealand agricultural production. This interest has been stimulated by the decline in price of the main primary products over the last decade and the present uncertain economic outlook, particularly for dairy products and lamb. A number of proposals have been made. One which has been made frequently and has been examined seriously on several occasions is the suggestion that New Zealand should produce sugar from domestically grown beet.

In 1960 a determined effort was commenced in South Otago to investigate the feasibility of a beet sugar industry centred on Balclutha. This investigation, initiated by the Otago Development Council and Otago Federated Farmers has studied the economics of factory operations and conducted trials to determine probable yields of sugar beet on farms in the district. There has, however, been no attempt to systematically study the Farm Management implications of the crop on individual farms. This thesis is primarily concerned with this aspect of the proposal and employs Linear Programming to clarify and analyse the problem.

One of the fundamental problems in empirical Farm Management Research is the difficulty, or even the impossibility of making detailed district recommendations on the basis of a sample survey of a restricted number of farms. It is well known, but not always fully appreciated, that the financial, physical and social circumstances of farmers often differ markedly. This difficulty is accentuated when a district has a multiplicity of soil types and land contours, particularly when this has resulted in the development of several distinct systems of farming. South Otago presents the analyst with these problems.

Another associated problem is that of estimating the changes and ramifications on the farm following the introduction of a new crop, with no commercial farming data and an extremely meagre supply of sound experimental data. An extensive experimental programme would be required to provide all the desired information. Since finance for research and the number of research workers are both limited, it was considered worthwhile - indeed essential - to make a preliminary assessment using the available data from Otago and the voluminous supply of overseas information, adjusted as far as possible for New Zealand conditions.

The outline of a research programme that would provide the necessary data to allow a confident decision on the advisability of establishing a Beet Sugar Industry is presented in Chapter 8.

Because of the analytical problems and the lack of reliable data, the detailed analyses in this study are confined to case farm situations in South Otago, which are believed to be reasonably representative of the soil type and contour described. This means that care should be taken in the interpretation of the numerical results. The appropriate adjustments must be made to the figures given and practices described here, when they do not exactly conform to any particular farm being analysed.

The key factor in the success or failure of a beet sugar industry is the attitude of the individual farmer. He is required to produce the raw material for processing and his problems and preferences as well as the price he requires should be adequately assessed before the project is taken very far. Both economic and sociological factors affect the individual farmer's decisions. Since the success of the industry will be affected by both factors, it is imperative that they be considered together.

A brief historical review of the world beet sugar industry and of the investigations that have been made in New Zealand is given in Chapter 2. Chapter 3 considers South Otago in relation to the technical requirements of sugar beet culture as far as they can be ascertained from overseas information, while the detailed results of the trial work that has been conducted in South Otago is presented in Chapter 4. Discussions of the farm survey methods used and the results, is given in Chapter 5 and the calculation of gross margins in Chapter 6.

The results of the Linear Programming analyses of three Case Farms is presented in Chapter 7. These results indicate that intensive sugar beet production either in association with wheat, or alone, could increase farm incomes substantially. The subjection of this increased income to progressive taxation would, however, detract from the apparent attractiveness of sugar beet production on individual farms.

The final chapter summarises the findings, draws some conclusions and makes recommendations for further research. The general conclusion is that the actual construction of a sugar beet factory should not commence for at least five years to give adequate time for a thorough examination of the whole subject.

Despite the problems and limitations discussed, it is hoped that this study will provide a basis on which farmers and their advisers can assess the merits of the crop and enable them to make an informed decision on whether to contract to grow sugar beet for any proposed factory. It should also give some guidance to potential investors and to those who have the responsibility of making policy decisions concerning the beet sugar industry in New Zealand.

CHAPTER 2

A BRIEF HISTORY OF SUGAR BEET IN NEW ZEALAND AND OVERSEAS

2.1 A HISTORICAL REVIEW OF WORLD SUGAR BEET PRODUCTION

The history of sugar goes far back into ancient times. Sugar cane was known in India and elsewhere in the Orient hundreds of years before the Christian era.

The art of crystallizing sugar was discovered in Europe during the fourth century A.D., but refining in the modern sense did not commence until the fourteenth century. Although the beet plant (Beta vulgaris) was known and cultivated more than two thousand years ago it was not until 1747 that the German chemist, Andreas Margraaf, proved that pure sucrose could be extracted from it in crystalline form. Forty years later Achard, a pupil of Margraaf, planted beets on a large scale and extracted a quantity of low grade sugar from them. The world's first beet sugar factory was erected in 1802 at Cunern in Silesia and proved to be commercially successful.

Little further development of beet sugar production occurred until the Napoleonic Wars when the French were deprived of cane sugar supplies from the West Indies by the naval blockade. After the successful production of sugar in France in 1811, Napolean decreed that a beet sugar industry be established.

Following the defeat of Napolean in 1815 and the lifting of the blockade, the accumulated supplies of West Indian sugar were dumped on the European market at low prices, causing the collapse of the beet sugar industry. However, improved manufacturing processes, nationalistic protective schemes and the emancipation of the slaves in the West Indies combined to make European beet sugar more "competitive" with tropical sugars. Indeed, by 1900 the industry was established in many European countries and surpassed cane as a source of sugar.

A great decline in beet production occurred during the First World War so that the war and post-war years were years of prosperity for cane producers. High prices were followed by the rapid development of new cane lands and the expansion of refining capacity. The productivity of cane lands was also greatly increased by the introduction of higher yielding strains. As the beet areas of Europe recovered from the War and with the growth of new protected industries (United Kingdom after 1924 and India after 1930) production rapidly outstripped demand.

In the late 1920's and early 1930's sugar prices fell, affecting both beet and cane producers. Acreage limitations were imposed by the main exporting countries under the "Chadbourne" Sugar Agreement of 1931. In 1937 the first International Sugar Agreement was signed but World War II commenced before it became effective. This war was fought over both cane and beet producing areas so that production of cane and beet sugar was adversely affected. After the war, sugar production increased rapidly and a new International Sugar Agreement was negotiated in 1953. This treaty was reviewed in 1956 and 1958 and remained in force until the end of 1963.

Figure 2.1 shows world production of centrifugal[(1)] sugar from 1879 to 1963 and also shows separately the production attributable to cane and beet.

Today, Norway and Portugal[(2)] are the only European countries not producing beet sugar and the industry has been set up in most of the remaining temperate zone countries of the world.

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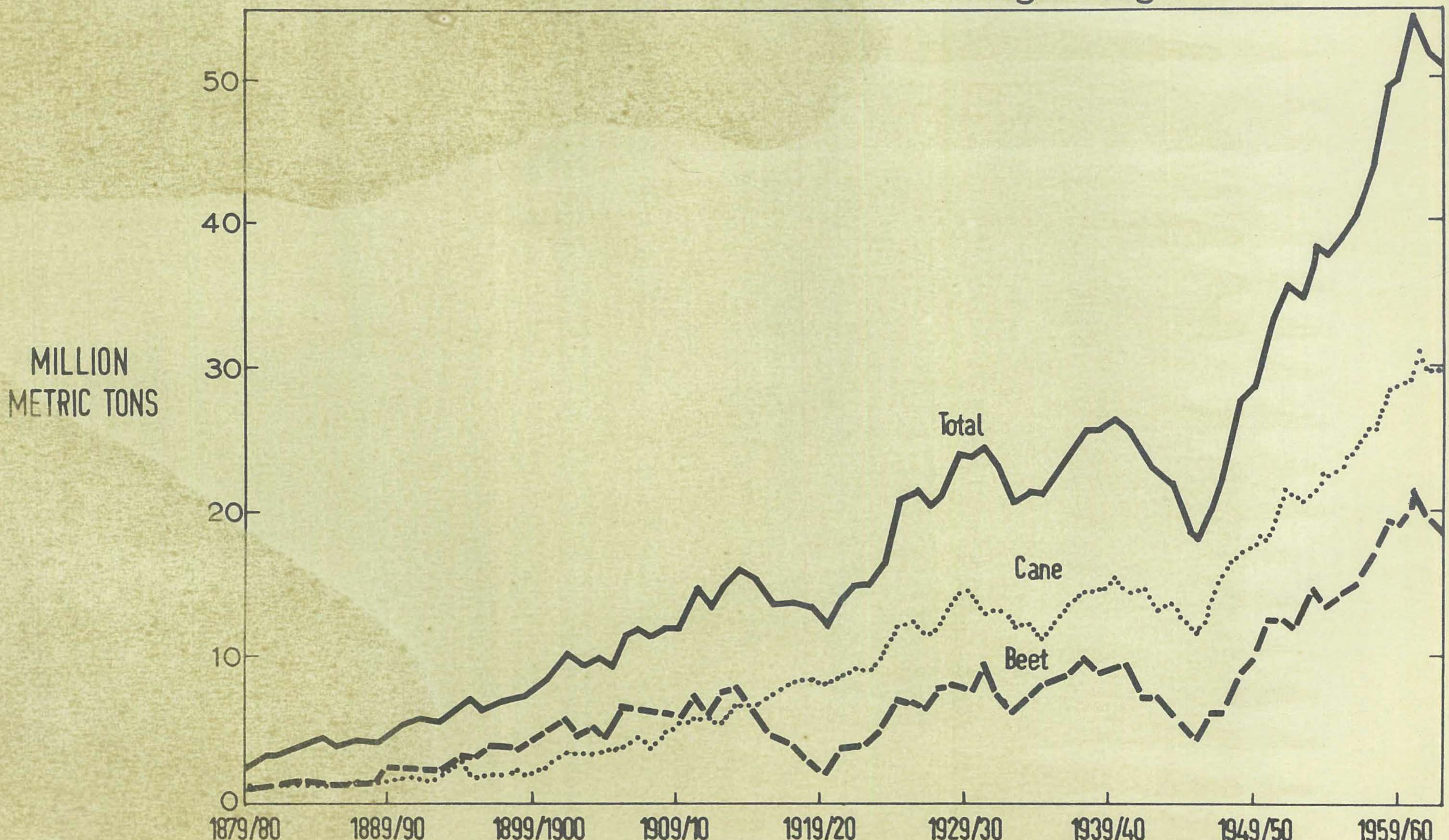
(1) As a centrifuge is used in the manufacture of high grade sugar, this is usually termed centrifugal sugar.

(2) Beet production has been carried on in the Portugese colony of Azores for some years and is planned on the Portugese mainland.

Fig. 2.1

World Production of Centrifugal Sugar



Source: The World Sugar Economy in Figures, 1880-1959, F.A.O., Rome, pp. 21-30, and Monthly Bulletins of Agricultural Economics and Statistics, F.A.O., Rome.

2.2 SUGAR BEET IN NEW ZEALAND, 1870-1950

Interest has waxed and waned over many years in the possibilities of a beet sugar industry for New Zealand. In 1870[3] the Joint Committee on Colonial Industries suggested that a bonus should be paid by the Government for home produced sugar from beets. It was not until 1877, however, that Parliament considered the matter and in that year passed a Bill offering £10,000 as a bonus for the first 1,000 tons of sugar produced from beets grown in New Zealand. In 1884 the Beet Root Sugar Act was passed, which offered a bonus of ½d per pound for the first 1,000 tons of locally produced sugar. Excise duty was always to be ½d per pound less than that on imported sugar and if, in the 15 years after the passing of the Act, the import duty was reduced or removed, a bonus would be paid as an equivalent. This Act was consolidated in 1908 and remained in force until 1957 when it was repealed by the Finance Act.

Starting in 1900, the Department of Agriculture has conducted numerous plot trials in most districts in New Zealand, but the first published references to a comprehensive investigation into the sugar beet industry do not appear until the early 1920's.

In 1921 Cockayne[4] reported on investigations he had made the previous year at the Maffra beet sugar factory in Victoria, Australia, and discussed the considerations for the establishment of a beet sugar industry in New Zealand. He listed the following cardinal factors for successful sugar beet production.

(a) An up-to-date manufacturing plant with the necessary labour and material for its optimum running.

(b) An adequate daily supply of beets of comparatively high sugar content to keep the factory at full capacity for approximately 100 days each year.

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(3) New Zealand Official Year Book, 1895, p.316.

(4) Cockayne, A.H., "The Beet Sugar Industry - Considerations for its Establishment in New Zealand", N.Z. Jnl. of Agric. 22: 6-12, 1921.

(c) A market value for refined sugar high enough to enable a price to be paid to the grower of beets which would yield him a per acre profit in excess of what he could realise for any of his then major crops.

Cockayne suggested that suitable soils for sugar beet production were, in general, those on which mangolds could be successfully grown, with the exception of heavy moist soils. Climatic conditions were considered to be of greater importance than soil type as a comparatively dry period was necessary during the latter part of the growing period and during lifting.

He said that it was of fundamental importance to consider the type of farming practiced in a district where sugar beet growing was proposed. Because of the necessity for large acreages of beet within a few miles of the factory, only districts where short-rotation pastures and where rotation farming were predominant need be considered. Where short rotation pastures were not predominant the area of land cultivated per farm would be so small as to render any successful beet establishment impossible without changing the farming practice and this would be unlikely until beet growing had been proved more remunerative than any other type of soil utilization. Only Canterbury, North Otago, Central Otago (under irrigation) and parts of Nelson and Marlborough were classed as potential beet areas.

Cockayne observed that the Maffra factory always ran below capacity because of an insufficient supply of beets. Numerous reasons for failure to secure an adequate tonnage were advanced, but the real one - that only a small proportion of the farmers of the district wanted to grow beets - was never stressed. A company could not rely on the farmers of a district to grow the necessary beets unless the price to the farmer, and consequently the price of sugar, was extremely high.

Cockayne concluded by saying that the high monetary return per acre[(5)] and the large amount of capital and labour that could be sustained put sugar beet

(5) The estimated return of £13 per acre was higher than that of competing crops.

production on a unique basis and warranted every consideration being given to any soundly based project.

No action was taken to establish the industry at the time and interest appears to have declined from 1921 onwards. In 1939, however, a detailed and comprehensive report covering many aspects of sugar beet culture and processing was presented to the Government by Pascoe.(6)

His first examination of the subject commenced in 1935, when, as a member of the Unemployment Board he was looking for possible industries to create employment. As a result of a favourable preliminary report, trials were carried out in the 1936-37 and 1937-38 seasons in areas considered suitable for the crop and Pascoe made an extensive overseas tour examining sugar beet farm and factory practices in Britain, Europe and the United States. Among his recommendations to the Government in the 1939 report were the following:

(a) That Mr T.M. Hayek, Director of the Irish Sugar Company Limited be asked to visit New Zealand to advise the Government on all aspects of a sugar beet industry.

(b) That a thorough study of the proposed beet growing area be undertaken. (The area between Timaru and Rangitata Island was suggested.)

(c) That expert consideration be given to the possibilities of irrigation as a means of increasing the yields per acre.

(d) That, as a sugar beet industry cannot function without its supply of raw materials, it would be necessary to survey the proposed beet growing area to secure the necessary undertaking from individual farmers to grow a continuous supply.

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(6) Pascoe, G.A., "Report on the Development of a Sugar Beet Industry in New Zealand". Presented to the Minister of Industries and Commerce, January 1939.

(e) That the desirability of the factory providing modern mechanised farm implements be considered and that these be operated by the staff of the factory as their operation would require highly skilled training, while farmers would know with greater certainty the actual costs of growing their sugar beet crops.

(f) That the manufacture of industrial alcohol in association with a sugar beet factory be investigated.

(g) That trials be carried out to determine the optimum methods of feeding the by-products to livestock.

It was proposed that a Sugar Corporation be established, the State to provide half the capital in ordinary shares and the remainder to be provided by State guaranteed debenture stock offered to the public and the beet growers. The assistance of the State was said to be counter-balanced by the employment created, the increase in domestic production, the saving of sterling reserves and the far-reaching benefits which would accrue to agriculture and the whole community.

Mr Hayek was duly invited. His investigations were interrupted by the outbreak of the Second World War, but he presented a report(7) in October 1939. He concurred with Pascoe's findings and recommended the erection of a factory at Orari to produce 30,000 tons of refined sugar annually. However, the War intervened and no action was taken on the report.

In 1946 the Department of Agriculture, in conjunction with the Department of Industries and Commerce, imported machinery of the latest design from the United States to test the economics of sugar beet production under full mechanization.(8) Large scale trials were conducted over three seasons in the Waimate district of South Canterbury. Each season four areas each of eight to

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(7) Hayek, T.M., "Report on the Development of a Sugar Beet Industry in New Zealand". Presented to the Minister of Industries and Commerce, 10 October 1939.

(8) Blackmore, L.W., "Trials with Sugar Beet Machinery in South Canterbury", N.Z. Jnl. of Agric. 83: 273, 1951.

ten acres were grown. These trials showed conclusively that the use of modern machinery could reduce the labour requirements per acre substantially. They also gave a better understanding of the types of soil on which the crop could be handled with reasonable efficiency. The hourly capacities of the machinery under New Zealand conditions were assessed.

The trials concluded in 1950 when the prices of farm products were buoyant and rising. Farmers were not interested in diversifying into a relatively labour intensive crop at that time, so again nothing eventuated and the machinery was ultimately sold.

2.3 SUGAR BEET IN NEW ZEALAND, 1950 ONWARDS

The subject was not publicly raised again until 1959, when Waters,(9) who had been associated with sugar analyses during the 1936-38 trials suggested that a beet sugar industry could be associated with the dairy industry. He suggested that sugar beet could be grown on dairy farms as a dual purpose crop in place of the usual winter feed root crop. As the crop is harvested in the autumn-winter period the water supply and steam generating plant of dairy factories could be used to extract and concentrate beet sugar for transport to refineries.

He stated that a well-planned project for beet sugar production would confer the following benefits:

(a) Stabilise or reduce the overseas exchange required for sugar.

(b) Provide a cash crop for dairy farmers, the value of which could be isolated from overseas market fluctuations, which cannot be said for dairy produce, i.e., New Zealand could subsidise sugar production but not butter production.

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(9) Waters, D.F., "A Possible Industry for New Zealand", Jnl. of N.Z. Institute of Chemistry 23(2): 37-43, 1959.

(c) Provide a new industry giving new jobs for full-time workers and work for seasonal workers.

(d) Increase coal consumption.

(e) Require considerable manufacture of agricultural machinery for handling the beet crop and processing machinery for extracting and refining sugar.

In 1960 Cutler[10] suggested that the sugar beet industry could possibly be successful in Southland. He said that sugar beet grew well there and there were adequate areas of suitable soils close to satisfactory sites for processing factories. Further, freezing works had steam raising capacity which could be used in winter for extracting raw sugar. In this paper Cutler said,

> "There may be reasons why a sugar industry would not be economic but from a soil point of view some serious investigations are necessary."[11]

The first suggestion that South Otago might be a suitable district was made in 1960. The Otago Development Council approached Otago Federated Farmers with the proposal that the possibility of establishing a sugar beet industry in South Otago be investigated.

At that time the economic outlook for meat, wool and dairy produce was bleak and Federated Farmers felt that the matter should be placed before the farmers of the district. The Balclutha and Kaitangata Businessmen's Associations, associated themselves with Federated Farmers and two large public meetings were held in the district at both of which it was agreed to set up an investigating committee to look into the question in detail. The main reasons advanced for this decision were:

(a) The advantage of diversified farming with little loss of present production.

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(10) Cutler, E.J.B., "The Soils of Southland and their Potential Uses". Proc. of 22nd. Conf. N.Z. Grassland Assoc. 22: 15-25, 1960.

(11) Cutler, E.J.B., op.cit., p.22.

(b) It appeared that South Otago was suited to the growing of sugar beet.

(c) The need for an industry to utilise Kaitangata coal.

(d) The possible integration of labour from the freezing works and sugar beet factory.

(e) Little extra labour would be required on farms due to the development of monogerm seed and complete mechanization.

(f) The saving of overseas exchange.

Farmers and businessmen have since subscribed capital to form the South Otago Sugar Beet Investigation Company, a public company established to fully investigate the industry.[12] Sugar beet trial work has been carried out over the 1961-62 and 1962-63 seasons and large scale trials are being grown this season (1963-64). The Company has also examined the economics of a beet sugar factory and in early 1963 an expert from the British Sugar Corporation was brought out to Otago to advise on all aspects of the proposal.

Thus considerable work has been carried out over the last fifty years on sugar beet in New Zealand, but no definite conclusions have been reached. Certainly, no action has been taken to establish the industry. The current investigations in South Otago are the most comprehensive and serious which have yet been made in New Zealand. This explains the choice of South Otago as the district studied in this thesis.

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(12) In 1962 the Taranaki Sugar Company was formed in Taranaki with similar aims.

CHAPTER 3

THE TECHNICAL REQUIREMENTS OF SUGAR BEET CULTURE AND THE SUITABILITY OF SOUTH OTAGO

The technical requirements of sugar beet production in New Zealand are not well known. Varietal trials have been carried out in many districts and one machinery trial conducted, but many other important matters have not been investigated under New Zealand conditions. It has been necessary, therefore, to use overseas technical data. Since British farming systems, in areas where sugar beet is grown are, to some degree, similar to those which could develop in New Zealand, English data has been the primary source of information. Sugar beet is extensively grown in the United States, but conditions bear no resemblance to those in Otago.

Although it is not the main purpose of this thesis to discuss the husbandry aspects of sugar beet production, a statement of the more important points is presented in Appendix I. It is of vital importance that the practical management implications of these requirements be fully appreciated by farmers and potential investors before active steps are taken to set up the industry. The main technical requirements are very briefly summarised below and, following a discussion of the value of the by-products of a sugar beet industry, are discussed in relation to conditions in South Otago.

3.1 CLIMATE

In the northern hemisphere beet is grown throughout the temperate zone. There is considerable diversity in the climatic conditions under which crops are produced, from the moist insular climate of the United Kingdom to the arid conditions in parts of the United States where irrigation is necessary. Thus sugar beet does not have very specific climatic requirements. However, it is considered desirable to have a long growing period, with rainfall well spread (in the absence of irrigation), followed by dry sunny weather during the month before lifting.

3.2 SOIL TYPE

Sugar beet grows best on naturally fertile soils but many soils that are inherently poor chemically can often grow beet successfully if they are suitably fertilized. The power of the soil to retain moisture or to lose excessive moisture is more important than its natural fertility. This is particularly important when it is planned to completely mechanize the growing and harvesting of the crop.

3.3 CONTOUR

The complete mechanization of sugar beet production requires very accurate cultural techniques. Rolling country would add, to varying degrees, to the difficulty of attaining the required degree of precision, but it has proved impossible to obtain any experimental data on the limitations sloping ground may place on the crop.

3.4 SUGAR BEET IN THE ROTATION

Sugar beet can follow most crops or permanent pasture in the cropping rotation provided previous crop residues have been placed well below the soil surface during ploughing. In Britain, sugar beet has replaced part of the fodder root acreage and cereals are considered the best crops to precede it.

3.5 SUGAR BEET CULTURE

All aspects of sugar beet culture require careful attention to detail and high standards of crop and mechanical husbandry. This applies to all operations from the initial ploughing and levelling of the paddock to the harvesting of the mature beet. A comprehensive discussion of seed bed preparation, fertilizer needs, drilling, thinning, weed and pest control and harvesting is given in Appendix I.

3.6 UTILIZATION OF BY-PRODUCTS

The by-products of the sugar beet crop, tops and pulp, are of value for feeding to almost all classes of livestock. This has resulted in a marked decrease in the acreage of feed roots where sugar beet is grown.

The tops (leaf and crown) can be used for feeding to livestock or for ploughing in as a green manure. In Britain today there is a tendency for few tops to be fed except where they can be fed off in breaks in the beet paddock after harvest. In the United States they are extensively made into silage. Tops are a valuable feed. They contain 15 to 17 per cent dry matter and are rich in protein and carbohydrate. Table 3.1 shows the comparable feeding values of beet by-products and other common root crops.

It can be seen from Table 3.1 that, after allowing for wastage when fed, one acre of beet tops yielding ten tons can be regarded as equal to half-an-acre of mangolds or swedes yielding 20 tons per acre. The tops should be allowed to wilt for at least three days before feeding, to reduce the oxalic acid content, otherwise scouring is likely to occur. If the tops are fed off on the paddock the manurial value is returned to the land and the feeding value is recovered in the liveweight increase of the animal. Tops are a valuable feed for sheep, cattle and dairy cows.

TABLE 3.1

COMPARATIVE FOOD VALUES OF VARIOUS STOCK FOODS

Foodstuff	Dry Matter (Percentage)	Starch Equivalent (Relative to Starch = 100)	Protein Equivalent (Percentage)
Sugar beet tops	16.2	8.6	1.2
Sugar beet top silage	23.0	9.5	0.8
Dried beet pulp-plain*	90.0	60.6	5.1
Dried beet pulp-molassed*	90.0	58.3	4.6
Pressed beet pulp*	18.0	14.0	1.2
Wet beet pulp*	8.5	6.6	0.6
Oats	86.7	59.5	7.6
Swedes	11.5	7.3	0.7
Kale - marrow stem	14.0	9.0	1.3
Mangolds	12.0	6.2	0.4
Turnips	8.5	4.4	0.4

* As produced by the British Sugar Corporation.

Source: Growers' Leaflet, Number Four, published by the British Sugar Corporation, London.

Beet pulp is the residue left when the sugar has been extracted from the roots. It is sold in several forms including wet pulp (82-92% water), pressed pulp (80-85% water), dried loose pulp either plain or molassed or, more recently, in nut form. Wet pulp is a good food for all ruminant animals. It is costly to transport and is best used on farms near the factory. It can be stored in clamps and silos and keeps well as long as sufficient provision is made for the disposal of the effluent.

Dried pulp is produced in large quantities by the British Sugar Corporation, the yield being approximately 1.2 cwt. of dried pulp per ton of topped and washed roots. Table 3.1 shows that it is a very valuable stock food, as it approaches oats in feeding value. Dried pulp can form part of a maintenance or production ration for all ruminant animals and can be fed in limited quantities to pigs.

The high food value of sugar beet by-products, together with the attractive price paid for beet delivered to the factory, explains why it has so rapidly replaced other forms of roots in districts where it is grown overseas.

3.7 SOUTH OTAGO IN RELATION TO THESE FACTORS

The following discussion refers to those districts within a thirty mile radius of Balclutha as this was the first proposed beet growing area for a factory situated at Balclutha. The supply area has since been extended to a fifty mile radius but the study of this larger area is beyond the scope of this enquiry.

3.7.1 Climate

Climatic conditions should be suitable over most of the area. The average annual rainfall at Balclutha is 25 inches, fairly evenly distributed, although there is often a dry period in January-February which could, on the clay loams, reduce sugar yields. Rainfall is higher in the Owaka Valley and to the south-east of Clinton ranging from 35 to 40 inches annually. Frost or snow damage may occur, infrequently, on the higher ridge country.

3.7.2 Soil Types and Contour

There are many soil types in the region together with widely differing topographical situations and the exact limitations of these two interacting factors are not clear. Overseas experience has shown that the cultural requirements of sugar beet are exacting. It is likely, therefore, that it would be more difficult and more expensive to grow the crop on rolling country. Sloping ground adds to the difficulty of precision sowing, thinning, weeding and lifting the crop. There would be uncropped land in many paddocks where the ground falls away sharply. Slopes would have to be attempted head-on and cross-slopes avoided. The current practice of fanning out on spurs when drilling swedes and turnips would not be acceptable when growing beet as a consistent row width is essential to the subsequent operations of hoeing, thinning and harvesting.

Difficulties would increase as the degree of slope increased. The operating costs of tractors would be higher because larger power units would be needed - powerful enough to deal with the steepest part of any paddock. Operations, particularly harvesting, would cease sooner during inclement weather, especially on the clay soils.

Two estimates of the area suitable for sugar beet have been made. They have been prepared using different assumptions and consequently different figures have been derived.

Mr R.C. Stephen of the Department of Agriculture has used the following criteria:

(a) The land must be capable of growing wheat well.

(b) The contour must be suitable for the efficient operation of self-propelled header harvesters.

Using these two assumptions, Table 3.2 has been derived to show the acreages of the various soil types that could be expected to grow sugar beet reasonably well in most seasons. Three divisions according to distance from Balclutha are shown. These indicate that 20,000 acres, 51,000 acres and 23,500 acres are 0-10 miles, 10-25 miles and 20-30 miles distant respectively. Figure 3.1 shows the general location of these soil types, but not all of the areas shown are suitable for beet production. The rolling country contains large areas that are too steep for arable farming. Land of suitable contour for sugar beet is scattered throughout the region shown.

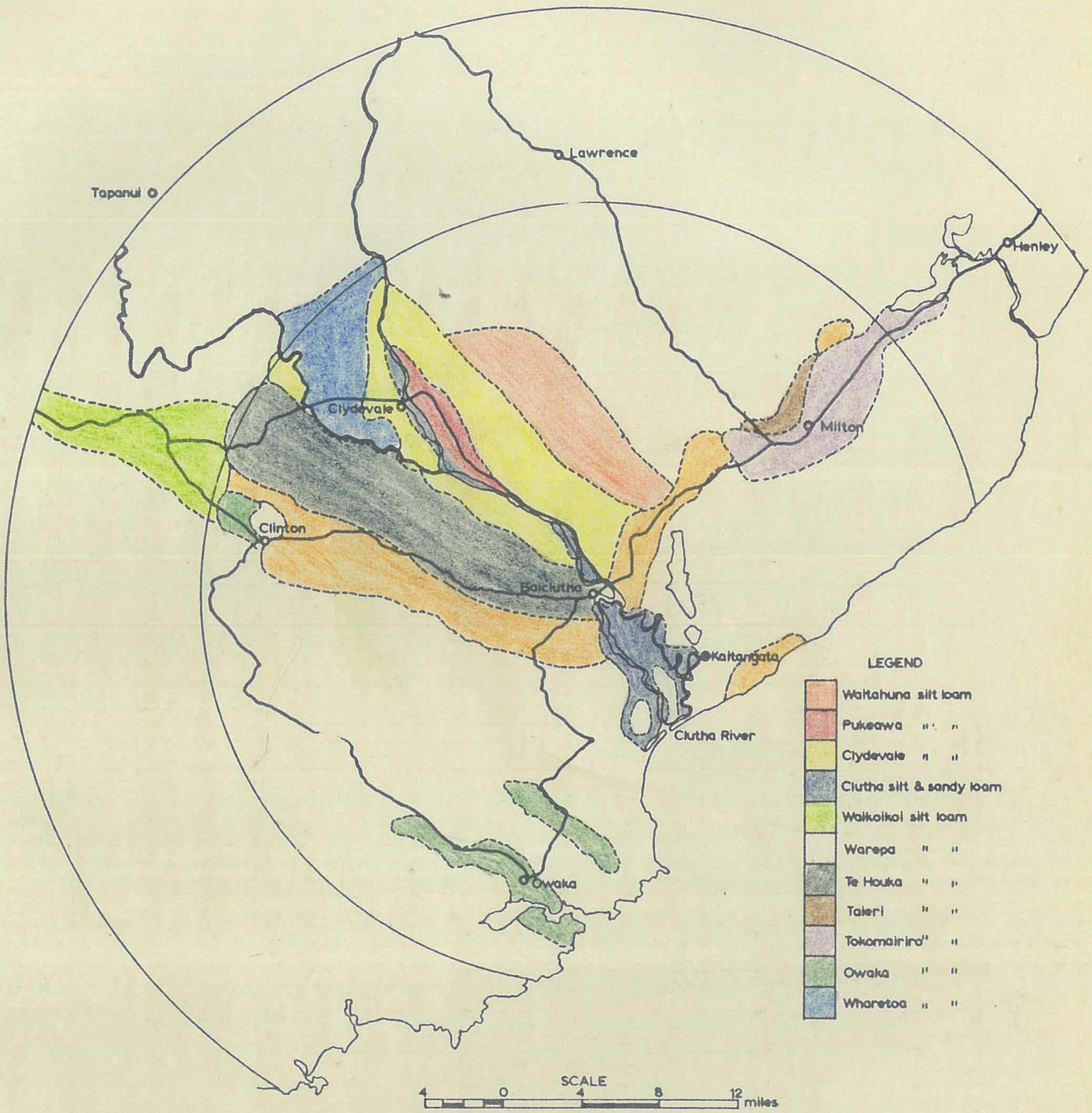
This estimate was made when sugar beet was first proposed as a possible crop in South Otago. Only limited information was available at the time and it was thought that any arable land of reasonable fertility and having a depth of top soil of 10-12 inches combined with a subsoil of satisfactory texture and having a flat to easy rolling contour would be suitable for sugar beet cultivation. In the case of South Otago, it was considered that topography would be one of the main limiting factors. In the absence of any practical experience in the operation of sugar beet machinery, it was considered that areas having a topography suitable for the efficient operation of a header harvester would most probably be suitable for the efficient operation of sugar beet seeding, inter-row cultivation and harvesting machinery. Experience will have been gained from the trial work conducted over the past two seasons and, after an evaluation of the current season's work with sugar beet machinery, these estimates may need to be modified and adjusted.

TABLE 3.2

THE AREA OF LAND SUITABLE FOR SUGAR BEET
BY DISTANCE FROM BALCLUTHA, ESTIMATED BY R.C. STEPHEN

Soil Type	Total Area	Mileage From Balclutha		
		0-10	10-20	20-30
		acres		
Clutha silt and sandy loam	7,000	5,500	1,500	-
Clydevale silt loam	15,000	1,000	11,000	3,000
Owaka silt loam	5,500	-	2,000	3,500
Pukeawa silt loam	4,000	-	4,000	-
Taieri silt loam	2,500	-	2,500	-
Te Houka silt loam	12,000	5,000	4,500	2,500
Tokomairiro silt loam	6,000	-	6,000	-
Waikoikoi silt loam	3,000	-	-	3,000
Waitahuna silt loam	7,500	-	5,000	2,500
Warepa silt loam	19,500	8,500	11,000	-
Wharetoa silt loam	12,500	-	3,500	9,000
TOTALS	94,500	20,000	51,000	23,500

Fig. 3·1 SUITABLE SOILS FOR SUGAR BEET - *Stephen*



Mr E.J.B. Cutler of the Soil Bureau has made an estimate based largely on pedological data from the four mile survey of the South Island. (He emphasises that this assessment should be checked in actual practice by trial work on the various soils.)

The criteria used were as follows:

(a) Deep friable soils (A and B horizons).

(b) Free draining soils (or easily drained).

(c) Texture range from silt loam to fine sandy loam to peaty loam.

(d) Medium to high fertility (or the likelihood of this being easily attained).

(e) Flat or gently undulating terrain. The Soil Bureau classifies "gently undulating" and "easy rolling" terrain as having most slopes under 5°. (1)

(f) Adequate soil moisture during the growing season.

(g) Absence of a hard pan in soils.

(h) Soils not liable to erode under cultivation.

Using these criteria Cutler has defined well suited, moderately suited and doubtfully suited soils for sugar beet. These soils are described below.

__Well suited:__ Recent soils (mostly well drained) of the Clutha and Mataura sets.(2)

__Moderately suited:__ Organic soils and recent gley soils (easily drained) of the Waitepeka and Koau (part) sets.

__Doubtfully suited:__ Yellow-grey earth intergrade soils (deep phases of the Clydevale set) and the yellow-brown earths of the Owaka set (undulating to easy rolling phases).

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(1) Taylor, N.H., and Pohlen, I.J., "Soil Survey Method", N.Z. Department of Scientific and Industrial Research, Soil Bureau Bulletin 25, pp.30-32, 1962.

(2) The soil set is a convenient mapping unit used on general surveys in New Zealand and is a grouping of soils with like profiles or like assemblages of profiles.
See Taylor, N.H., and Pohlen, I.J., __op.cit.__, p.143.

Table 3.3 shows the distribution of these soils according to the distance from Balclutha. The location of these soils is shown in Figure 3.2.

TABLE 3.3

THE AREA OF LAND SUITABLE FOR SUGAR BEET BY DISTANCE FROM BALCLUTHA, ESTIMATED BY E.J.B. CUTLER

"Suitability"	Total Area	Mileage from Balclutha		
		0-10	10-20	20-30
		acres		
Well suited	22,527	13,312	2,764	6,451
Moderately suited	15,155	8,499	-	6,656
Doubtfully suited	33,893	716	27,648	5,529
TOTALS	71,575	22,527	30,412	18,636

On the basis of the Soil Bureau assumptions, Table 3.3 shows that 22,527 acres, 15,155 acres and 33,893 acres may be described respectively as well suited, moderately suited and doubtfully suited to sugar beet production.

Cutler[3] states that most of the soils of South Otago have been placed in the unsuitable category because of more than one limiting factor. Most of the soils are on rolling or strongly rolling land with many deep gullies and areas of easy land are restricted to narrow winding ridgetops. These soils have hard pans, which restrict root growth and many have wet horizons below the top soil as well. They have wide seasonal moisture regimes and can be affected by drought in dry seasons and pug easily in wet years.

The soils of the "clay" downs[4] have weak structures and in the past have suffered much sheet erosion when cultivated for cereals. Much of the damage due

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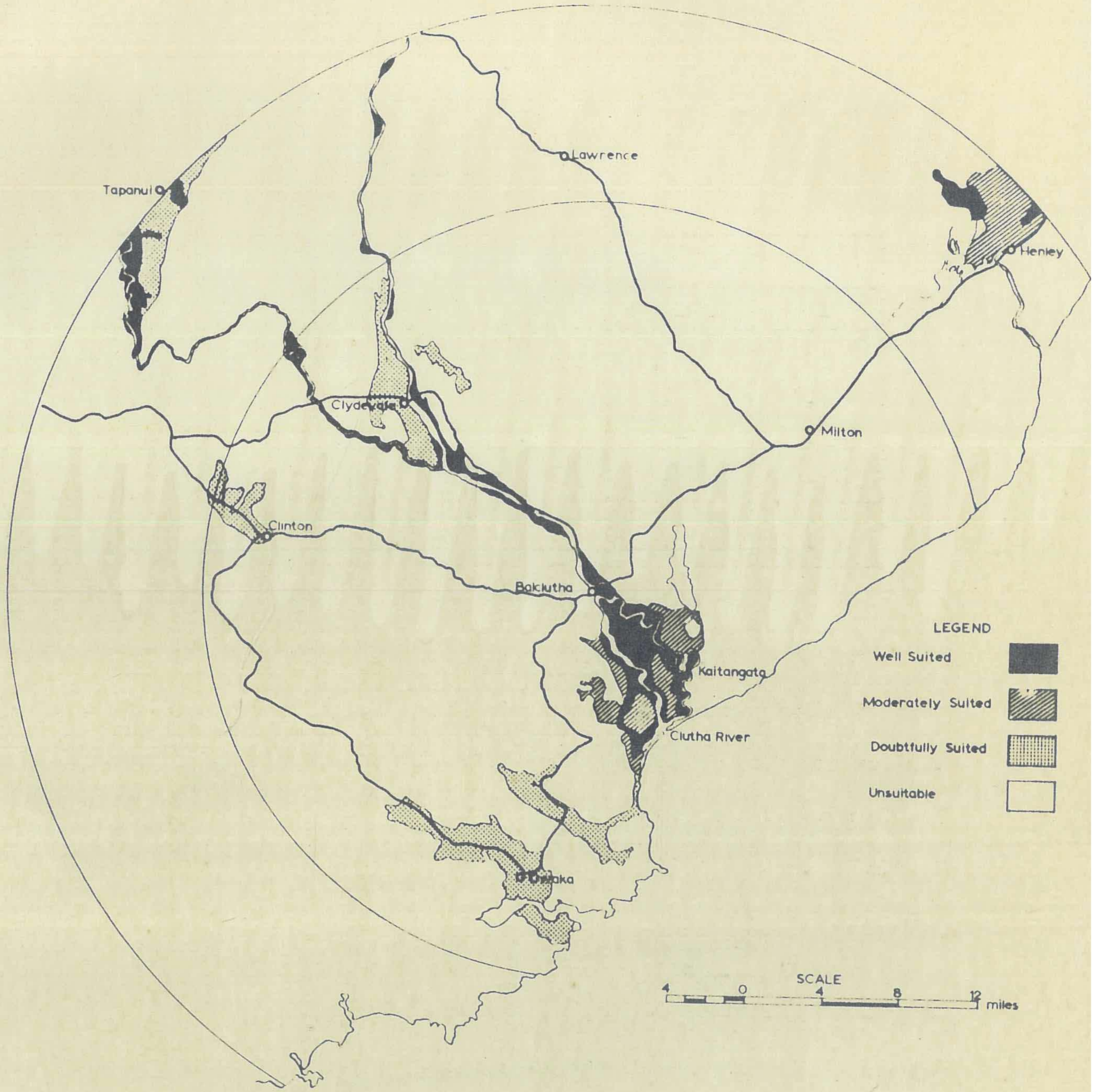
(3) Cutler, E.J.B. Personal communication.

(4) Yellow-grey earths of silt loam texture are commonly referred to as "clay" downs.

Fig. 3·2 SUITABLE SOILS FOR SUGAR BEET - *Cutler*



to sheet erosion has still not been repaired. Cultivation of these soils to a fine tilth and the introduction of a shorter rotation may again lead to deterioration of structure and the renewal of sheet erosion.

The author is not qualified to comment on the validity of either estimate but it is apparent that further work is needed to determine accurately the limitations of South Otago soils. However, the acreage of sugar beet required annually to supply a factory of any given capacity can be calculated from the following formula.

$$A = \frac{O}{ECY}$$

where A = Acreage required

O = Factory output (tons)

E = Sucrose extraction rate (per cent)

C = Sucrose content (per cent)

Y = Yield (tons per acre of topped and washed beet).

Table 3.4 has been constructed to show the area of land required to grow sugar beet under various conditions. The yield of topped and washed beet and the sucrose content have been varied. An output of 30,000 tons of refined sugar has been assumed because much of the public discussion has referred to a factory of this size. Since the sucrose extraction rate in Britain is approximately 85 per cent, this value has been used in the calculations.

Column (1) in Table 3.4 shows the actual acreage of sugar beet required to supply a 30,000 ton factory. However, the area of land required to sustain a given beet acreage depends on the length of the rotation. Thus columns (2) to (5) indicate the total area of land required as the length of the rotation (including one crop of sugar beet) is increased from one year in four to one year in ten.

TABLE 3.4

THE ACREAGE REQUIRED TO GROW SUGAR BEET FOR A 30,000 TON FACTORY AT VARIOUS YIELDS, SUCROSE CONTENTS AND ROTATION LENGTHS

Yield (tons/acre)	Acreage in Sugar Beet	Rotation Length			
		1:4	1:6	1:8	1:10
	(1)	(2)	(3)	(4)	(5)
	Thousand Acres				
<u>Sucrose 14%:</u>					
10	25.2	100.8	151.2	201.6	252.0
15	16.1	64.4	96.6	128.8	161.0
20	12.6	50.4	75.6	100.8	126.0
25	10.1	40.4	60.6	80.8	101.0
30	8.4	33.6	50.4	67.2	84.0
<u>Sucrose 16%:</u>					
10	22.1	88.4	132.6	176.8	221.0
15	14.7	58.8	88.2	117.6	147.0
20	11.0	44.0	66.0	88.0	110.0
25	8.8	35.2	52.8	70.4	88.0
30	7.4	29.6	44.4	59.2	74.0
<u>Sucrose 18%:</u>					
10	19.6	78.4	117.6	156.8	196.0
15	13.1	52.4	78.6	104.8	131.0
20	9.8	39.2	58.8	78.4	98.0
25	7.8	31.2	46.8	62.4	78.0
30	6.5	26.0	39.0	52.0	65.0
<u>Sucrose 20%:</u>					
10	17.6	70.4	105.6	140.8	176.0
15	11.8	47.2	70.8	94.4	118.0
20	8.8	35.2	52.8	70.4	88.0
25	7.1	28.4	42.6	56.8	71.0
30	5.9	23.6	35.4	47.2	59.0

Table 3.4 shows a range in the area of land required from 23,600 to 252,000 acres. This emphasises the need for accurate information on yield, sucrose content and length of rotation before the requirements of land can be determined.

3.7.3 Sugar Beet Rotations

Some insight into the demands on the available land, within a 30 mile radius of Balclutha, can be gained if the following assumptions are made.

(a) An average yield of correctly topped and washed beet of 17.5 tons per acre.(5)

(b) A sugar content of 16%.(5)

(c) That Cutler's estimate of 22,500 acres of well suited soils are capable of growing sugar beet once every five years.

(d) The difference between this figure of 22,500 acres and Stephen's estimate of 94,500 acres (i.e., 72,000 acres) is suited to sugar beet but in a longer rotation.

(e) There is 100 per cent participation by farmers with suitable land.

Under these conditions 12,600 acres of beet will be required to supply a 30,000 ton factory. The better land (22,500 acres) will contribute 4,500 acres of beet while the balance of 8,100 acres can be grown on the poorer land (72,000 acres) in a one in nine year rotation.

On the highly fertile flat land it would be feasible to consider a one in five rotation of sugar beet worked in with cereals and some potatoes. The sugar beet by-products could provide most of the supplementary feed required by dairy herds and sheep flocks. It may be necessary for some beet to follow and be followed by pasture.

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(5) Mr J. Campbell MacDonald, Chief Technical Officer of the British Sugar Corporation, used these figures in his first interim report to the Directors of the South Otago Sugar Beet Investigation Company. See the questionnaire circulated by the Company in June 1963. Actual trial results are discussed in Chapter 4.

Weed control would be a major problem on this land. Extensive hand weeding and thinning of mangold and swede crops is carried on at present, particularly on the rich delta land.

Some soils along the Clutha and Pomahaka Rivers are not protected from flooding and, therefore, in some seasons, would be liable to inundation. The last major flood in 1957 caused losses estimated at £538,000 and the annual loss after fifty years is assessed at £67,000. River control works costing £1,365,000 are in the process of construction and should protect most of the area from serious flooding. When complete, some 7,400 acres of undeveloped land will be drained and should, ultimately, provide additional land suitable for intensive beet cultivation.

On the "ridge" or rolling country sugar beet would be incorporated into a long term rotation with pastoral farming, winter roots and wheat, because only a proportion of the land on these farms is suitable for arable farming.

There is, at present, no settled rotation generally used in the district. With the application of more fertilizer and the introduction of improved species of grasses and clovers the pasture growing season has lengthened significantly thus reducing the need for large acreages of winter fodder crops. Well managed pastures retain their productivity and vigour for ten to fifteen years and there is a general reluctance to plough good pasture. Wheat growing is increasing rapidly, especially since the introduction of grain driers, as farmers respond to the favourable wheat prices. New rotation plans would have to be devised if sugar beet was introduced but it would be expected to substitute for winter roots and more wheat would probably be grown on many farms.

3.7.4 Sugar Beet Culture

It is clear from the discussion of the technical requirements of sugar beet that considerable care and skill is required if the crop is to be successfully grown. It is probable that the cultural standards necessary for all phases of beet production are of a higher standard than those currently used in South Otago. Those farmers in the area who are now growing crops on a relatively large scale, and using intensive field husbandry methods, could probably handle the crop adequately. There are very few farmers in this category. Where less thorough and painstaking methods are used, some seasons may elapse before the necessary skills are acquired. If farmers are keen to grow the crop they will learn the new skills rapidly but, in the absence of some enthusiasm, results may be disappointing for the first few seasons.

3.7.5 The Utilization of By-products

The complete utilization of tops and crowns may present problems particularly on sheep farms. Dairy farmers, who are accustomed to long hours of feeding supplementary crops, for up to six months of the year, will probably make full use of them and be willing to make any surplus into silage. The tops will be available to sheep farmers in April, May and June when supplementary feed is not normally required. Some could be used for fattening late lambs and cattle and for feeding to the ewe flock enabling more grass to be saved, but if up to 10 per cent of the farm is in beet, a surplus will probably result. Sheep farmers may be reluctant to make silage and tops may be ploughed in on many farms, especially if weather conditions made it impossible to feed them off on the paddock.

A factory with an output of 30,000 tons of refined sugar would produce 13-14,000 tons of dried pulp (or its equivalent). Since there is a limited market for concentrated stock foods in South Otago, it is unlikely that this quantity could be sold locally, at remunerative prices, unless an intensive cattle feeding industry was developed. However, the South Otago Sugar Beet Investigation Company has quoted a price of £15 per ton for dried pulp in their 1963 brochure.

At this price, which is very much lower than the prices of equivalent stock-foods, it may be possible to sell the pulp throughout the South Island, particularly to the Town Milk Industry.

3.7.6 Summary

The discussion in this Chapter has shown that, unless yields and sucrose contents are high and (or) rotations are short, it is unlikely that there is sufficient suitable land within a 30 mile radius of Balclutha to support a 30,000 ton sugar beet factory. (See Table 3.4.) This becomes even more apparent if the assumption of 100 per cent farmer participation in the project is relaxed. As economies of scale are important in beet processing plants, a factory of lower capacity may not be feasible. It is probable that processing costs per ton rise sharply as capacity falls below 30,000 tons of refined sugar. Thus it is essential that an accurate estimate of the area of suitable soils in South Otago be made before the project is taken very far. An experimental programme that would provide a reliable estimate is outlined in Chapter 8.

CHAPTER 4

SUGAR BEET EXPERIMENTATION IN SOUTH OTAGO

4.1 TRIAL WORK CONDUCTED IN SOUTH OTAGO BY THE DEPARTMENT OF AGRICULTURE

Sugar beet trials have been conducted by the Department of Agriculture in many areas in New Zealand over the last fifty years. Only those located in South Otago since 1935 are discussed in this section.

As a result of Pascoe's preliminary report to the sugar beet committee of the Department of Industries and Commerce in 1935, the Fields Division of the Department of Agriculture was requested to conduct comprehensive varietal trials in various parts of the country. Investigations were carried out to obtain data on yields and sugar content. Two types of trial were used. The first was a small scale trial, sown by hand, and comparing ten varieties of sugar beet. The second type was a large scale trial occupying one acre and consisting of four blocks, three blocks each containing a single variety and the fourth being a replicated variety trial similar to the small scale trials.

The varieties used in these trials were those widely grown in Britain at the time and recommended by the National Institute of Agricultural Botany.

The large blocks containing the three main varieties were divided into three transverse sections, each section having a different manurial treatment. Various combinations of superphosphate, potash salts and nitrogenous fertilizers were used.

Of the 29 trials conducted in various parts of New Zealand in the 1936-37 season, three were located in South Otago. Two large scale trials, one at

Inchclutha and one at Taieri, and one small scale trial at Taieri were laid down. Spring and summer conditions were very wet and, in Otago, heavy rain and flood ruined some of the trials. Wet conditions after sowing resulted not only in very thick strikes but also in excessive weed growth, making singling and cultivation both costly and difficult. The three trials were so adversely affected by the bad conditions that they were not sampled.

In the 1937-38 season one trial was located at Inchclutha. It was successfully grown and the average yield of eight varieties was 32.1 tons of beets per acre, giving 5.3 tons of sucrose per acre. This yield of sucrose was one of the two highest in the country for that season.

These series of trials were continued in the 1938-39 and 1939-40 seasons in Canterbury. No further official trials were conducted in South Otago until the 1962-63 season when two small scale replicated variety trials were sown. These trials are discussed in some detail for they constitute the bulk of the reliable data.

4.1.1 Varieties Used in 1962-63

For these trials the following nine varieties were chosen:

1. Sharpe's Klein E (natural seed)
2. Sharpe's Klein E (rubbed seed)
3. Bush E (rubbed seed)
4. Bush N (rubbed seed)
5. Bush N (natural seed)
6. Sharpe's Polybeet (a polyploid variety)
7. Trirave (also known as Triplex M)
8. Monogerm Triploid
9. Russian

The trials were sown in randomised block design, with five replications. Individual plots consisted of one row 33 feet long with inter-row spacing of 22 inches. The seed was hand sown with seeds at two inch spacing and the plants later thinned to ten inch spacings.

4.1.2 Plant Counts Soon After Germination

A specific feature investigated by the Department of Agriculture was the number of single plants produced from the germinated seed of each variety. Natural, rubbed, polyploid and monogerm were expected to produce different proportions of single plants at germination.

A summary of plant counts over the whole country was as follows:

(a) Monogerm triploid was outstanding in producing approximately 90 per cent singles from germinated seed.

(b) Polyploid Trirave (Triplex M), Sharpe's Polybeet and Sharpe's Klein E (rubbed) produced approximately 70 per cent of singles.

(c) There was an appreciable difference between Sharpe's Klein E natural and rubbed seed. The treatment of rubbing increased the percentage of singles from 40 per cent to 70 per cent.

(d) The rubbing treatment in the case of Bush N had little effect in changing the occurrence of singles as judged by its comparison with natural seed of the same variety.

(e) Natural seed was characterised by many multiple emergences.

4.1.3 Replicated Variety Trials in South Otago

Details of the replicated variety trials are given in Table 4.1.

TABLE 4.1

SOUTH OTAGO TRIALS

Location	Glenore	Outram
Date Sown	24.10.62	8.11.62
Soil Type	Warepa silt loam	Clutha silt loam
Previous Crop	1961-62 wheat 1960-61 swedes after pasture	Pasture
Fertilizer per acre	Proprietary mixture 3 cwt.	Reverted super 1.5 cwt. Borated super 1.75 cwt. Nitrolime 1.0 cwt.
Date of harvest	7.5.63	20.5.63

Table 4.2 shows the results of plant counts soon after germination. Statistical tests using Duncan's Multiple Range Test[1] are shown. The first column lists the key for identifying the varieties in subsequent tables.

TABLE 4.2

PERCENTAGE OF SINGLE PLANTS

Key	Variety	Outram	Glenore
MT	Monogerm Triploid	94 aA	92 aA
T	Polyploid Trirave	76 bB	77 bAB
P	Sharpe's Polybeet	68 bBC	76 bcAB
KER	Sharpe's Klein E (rubbed)	66 bcBC	63 cdBC
BER	Bush E (rubbed)	50 cdCD	54 deCD
BNR	Bush N (rubbed)	27 eE	53 deCD
BNN	Bush N (natural)	43 deDE	40 eDE
KEN	Sharpe's Klein E (natural)	32 eDE	42 eCDE
R	Russian	30 eDE	23 fE
	C.V. (%)	15.0	16.7

4.1.4 Detailed Results

The trials were harvested and weighed (separately for tops and roots) and were sampled for dry matter content of tops and roots and sucrose content of roots. The results are tabulated in Tables 4.3, 4.4, 4.5 and 4.6.

(1) Duncan, D.B., "Multiple Range and Multiple F Tests", Biometrics 11: 1, 1955.
The test is interpreted as follows:
(a) Any two varieties or treatments are significantly different if they do not have the same letter in common.
(b) Any two varieties or treatments are not significantly different if they do have the same letter in common.
(c) Capital letters refer to differences significant at the 1% level of probability and lower case letters refer to differences significant at the 5% level of probability.
(d) The higher the mean, the nearer will the letter be to the beginning of the alphabet.

TABLE 4.3

PERCENTAGE AND YIELD OF SUCROSE

Variety	Percentage Sucrose in Roots		Yield of Sucrose : Tons p/ac.	
	Glenore	Outram	Glenore	Outram
MT	19.1	16.3	4.57 abA	3.02 bA
T	19.0	16.2	4.52 abA	3.43 abA
P	19.4	17.6	3.95 bA	3.28 abA
KER	19.3	17.1	4.60 aA	3.49 abA
BER	19.4	16.0	4.56 abA	3.55 aA
BNR	18.7	16.4	4.05 abA	3.50 abA
BNN	19.1	16.1	4.20 abA	3.38 abA
KEN	19.3	16.0	4.55 abA	3.10 abA
R	19.7	15.5	3.98 abA	3.04 bA
C.V. (%)			9.8	10.0

TABLE 4.4

DRY MATTER PERCENTAGE IN ROOTS AND TOPS

Variety	Dry Matter % in Roots		Dry Matter % in Tops	
	Glenore	Outram	Glenore	Outram
MT	27.0	23.9	15.9	13.7
T	26.3	22.6	14.5	15.2
P	27.3	24.7	18.2	16.2
KER	26.5	23.6	14.6	15.3
BER	26.8	22.5	15.1	14.0
BNR	26.4	23.9	14.3	13.9
BNN	26.3	23.2	14.7	14.5
KEN	26.9	23.6	16.9	14.3
R	27.1	22.7	15.1	13.1

TABLE 4.5

ESTIMATED* GREEN YIELDS OF BULBS AND TOPS
(TONS PER ACRE)

Variety	Bulbs		Tops	
	Glenore	Outram	Glenore	Outram
MT	22.0	18.5	19.1	23.1
T	21.6	21.3	15.8	18.7
P	15.8	18.6	14.3	17.5
KER	21.9	20.3	15.1	20.3
BER	21.2	22.5	17.1	22.4
BNR	18.3	21.2	17.9	20.2
BNN	19.4	21.0	20.8	15.4
KEN	21.2	19.4	15.7	18.7
R	15.9	19.6	18.3	25.1

* The estimate was obtained by converting from percentage dry matters.

TABLE 4.6

DRY MATTER YIELDS OF BULBS AND TOPS
(TONS PER ACRE)

Variety	Dry Matter Yields of Bulbs		Dry Matter Yields of Tops	
	Glenore	Outram	Glenore	Outram
MT	6.0 aA	4.4 bA	3.0 aAB	3.2 abA
T	5.7 abA	4.8 abA	2.3 bAB	2.8 abA
P	4.3 bA	4.6 abA	2.6 abAB	2.8 abA
KER	5.8 abA	4.8 abA	2.2 bB	3.1 abA
BER	5.7 abA	5.1 aA	2.6 abAB	3.1 abA
BNR	4.8 abA	5.1 aA	2.6 abAB	2.8 abA
BNN	5.1 abA	4.9 abA	3.0 aAB	2.2 bA
KEN	5.7 abA	4.6 abA	2.7 abAB	2.7 abA
R	4.3 bA	4.5 bA	2.8 abAB	3.4 aA

Table 4.3 shows that sucrose percentages and sucrose yields per acre were consistently higher at Glenore.

The very high dry matter content of sugar beet bulbs is shown in Table 4.4, that of the tops being considerably lower. When converted to a fresh weight basis the bulbs yielded approximately 20 tons per acre and the tops a little less. There were no consistent yield differences between varieties.

It should be emphasised that these trials were on a small scale and were very efficiently conducted. High standards of field husbandry would be required to reproduce these results on a farm scale.

4.2 TRIALS CONDUCTED BY THE SOUTH OTAGO SUGAR BEET INVESTIGATION CO. LTD.

In the 1961-62 season 38 farmers grew trial plots of sugar beet. The season was considered an exceptionally good one for root crops. These crops were sampled and tested in April and again in May 1962. Five plants were randomly selected from each plot, weighed, and the yield estimated by using an assumed standard plant population per acre. The sucrose content was calculated from pocket refractometer readings.

The results have been summarised as follows:

TABLE 4.7

COMPANY TRIALS : 1961-62

	April Test		May Test	
	English* Seed	U.S.A.** Seed	English* Seed	U.S.A.** Seed
Bulbs (tons per acre)	29.0	24.5	35.5	27.5
Sucrose (%)	15.87	18.37	15.10	18.30

* Multigerm Seed ** Monogerm Seed

During the 1962-63 season trials were again laid down by the Company. These trials were tested and analysed by the Department of Agriculture. Owing to late arrival of seed in New Zealand the trials were late sown and then encountered a dry spell. Sixteen of these trials were sown. Nine were successfully completed, the remainder being abandoned due to poor establishment and weed infestation.

The method of sampling was to dig and weigh ten feet lengths of two inside rows in two positions in each plot. The weights of these samples were averaged and the resultant figure used to determine the yield per acre. Tops and bulbs were weighed separately. Bulb yields ranged from 5.3 to 12.9 tons per acre.

The more important results are given in Table 4.8. These show that the Company trials have given much lower sucrose yields than the official Department of Agriculture trials in 1962-63. This is significant and can be regarded as some measure of the difference to be expected between commercial production of sugar beet and the results of efficiently conducted small scale experimental trials.[2]

Experimental work by both the Department of Agriculture and the Investigating Company are continuing in the present season (1963-64) but the results are not available for inclusion in the present study. However, a description of the trials up until March 1964 is given.

Five sites, each of 2 to 4 acres, were selected with the objective of growing beet through to harvest using mechanical methods only. The six areas are briefly described below.

<u>Site 1</u>: A rectangular level site on the Clutha silt and sandy loam soil, previously cropped with swedes.

<u>Site 2</u>: A level site, near the coast, on the Warepa silt loam, previously cropped with choumoellier.

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(2) Davidson, B.R., "Crop Yields in Experiments and on Farms", Nature, <u>194</u> (4872): 2, May 5, 1962.

TABLE 4.8

COMPANY TRIAL ANALYSES : 1962-63

Locality	G.W.* Monogerm	G.W.* A.214	G.W.* A.214 (Segmented)	G.W.* 737	Webbs 392	Battles E
Percentage Sucrose:						
Romahapa	18.6				19.5	
Wangaloa	16.8				17.0	
Wharetoa	16.7					15.6
Moneymore	19.1			18.8		
Milton	18.7	17.5		17.5	19.0	
Hillend	15.3				15.3	
Owaka	18.0	16.0	15.3	15.9		
Kuriwao	16.2			16.2		
Inchclutha	16.0		16.0			
Tons of Sucrose per acre:						
Romahapa	1.63				1.17	
Wangaloa	1.83				1.89	
Wharetoa	1.62					0.93
Moneymore	1.93			1.84		
Milton	1.62	1.58		1.32	1.04	
Hillend	1.34				1.13	
Owaka	2.19	1.82	1.60	1.62		
Kuriwao	1.46			1.41		
Inchclutha	1.67		2.00			

* Great Western. These are lines of seed obtained from the Great Western Sugar Company, Denver, Colorado, U.S.A.

<u>Site 3</u>: Two acres of a May ploughed paddock on rolling hill land, previously cropped with wheat. The soil type is the Warepa silt loam.

<u>Site 4</u>: A similar area to Site 3.

<u>Site 5</u>: A level hill paddock, previously in grass on the Clydevale silt loam.

A sixth site in West Otago has been used, but this is outside the district considered in this study.

The cultural operations at all sites were supervised by Officers of the Department of Agriculture. A fertilizer mixture of 3 cwt. of boronated super with DDT and Aldrin, to control any grass grubs or spring tails, plus 2 cwt. of Nitro-lime was applied to all areas. Soil tests were carried out to determine the requirements of potash and lime and these were applied where necessary.

The mechanization trial areas were sown with Sharpe's Klein E rubbed and graded seed. It was used because it has given consistently high yields with high sucrose contents in New Zealand trials and, although it has not the monogerm characteristic, it is more resistant to bolting and virus yellows than any of the true monogerm varieties.

The seed was sown in late September and early October with spacing drills loaned to the Investigation Company by two commercial firms. All mechanization trial plots were drilled on the flat at a row width of 20 in. and at a seed spacing of 1.5 in. Germination was good and the crops started off well.

As chemical means of weed control were not used on the main mechanization areas, it was imperative that mechanical weed control work be of a high standard. The Company provided a tractor and a driver who was responsible for all the row crop work. Two types of steerage hoe and three types of thinning machine were used. The results of this work were excellent and weeds were well controlled until the beet foliage met over the rows.

Harvesting is planned to commence in April using two types of machine. It is planned to harvest each crop in one attempt because this would give more opportunity for devising and developing a system of working under the particular conditions of each site, and give a rate of working more representative of that likely to be obtained in practice.

In association with the large mechanization trials, varietal, fertilizer and weed control trials have also been laid down by the Department of Agriculture while the Plant Diseases Division of the Department of Scientific and Industrial Research has been examining crops for pests and diseases. Beet storage and handling problems are also to be studied.

Although this work is more comprehensive than any previously attempted in the district, it is being conducted on a very small budget and perhaps should be regarded as a sugar beet demonstration rather than a properly designed and executed trial. The outline of a really adequate programme of trial work to answer the many important questions on sugar beet husbandry, under New Zealand conditions, is presented in Chapter 8.

CHAPTER 5

THE SOUTH OTAGO FARM SURVEY

In March and June 1963 the author visited 34 farms in South Otago. This survey is discussed in the present chapter.[1] The survey area is confined to the region within a thirty mile radius of Balclutha and the location of the farms visited is shown in Figure 5.1.

5.1 THE PURPOSE OF THE SURVEY

The survey was designed for two main purposes:

(a) To select farms from which sufficient data could be obtained to enable the hypothesis, that sugar beet is a profitable crop for inclusion in particular South Otago farming systems, to be tested.

(b) To familiarise the author with farming conditions generally, in the district.

The term "farm survey" is used here to mean a series of interviews with farmers to gain information about the profitability of their present enterprises, details of their current farm management practices and to discuss with them the technological changes which may be associated with sugar beet culture.

Agriculture is increasingly subject to rapid technological change and Farm Management research workers are becoming more concerned with determining

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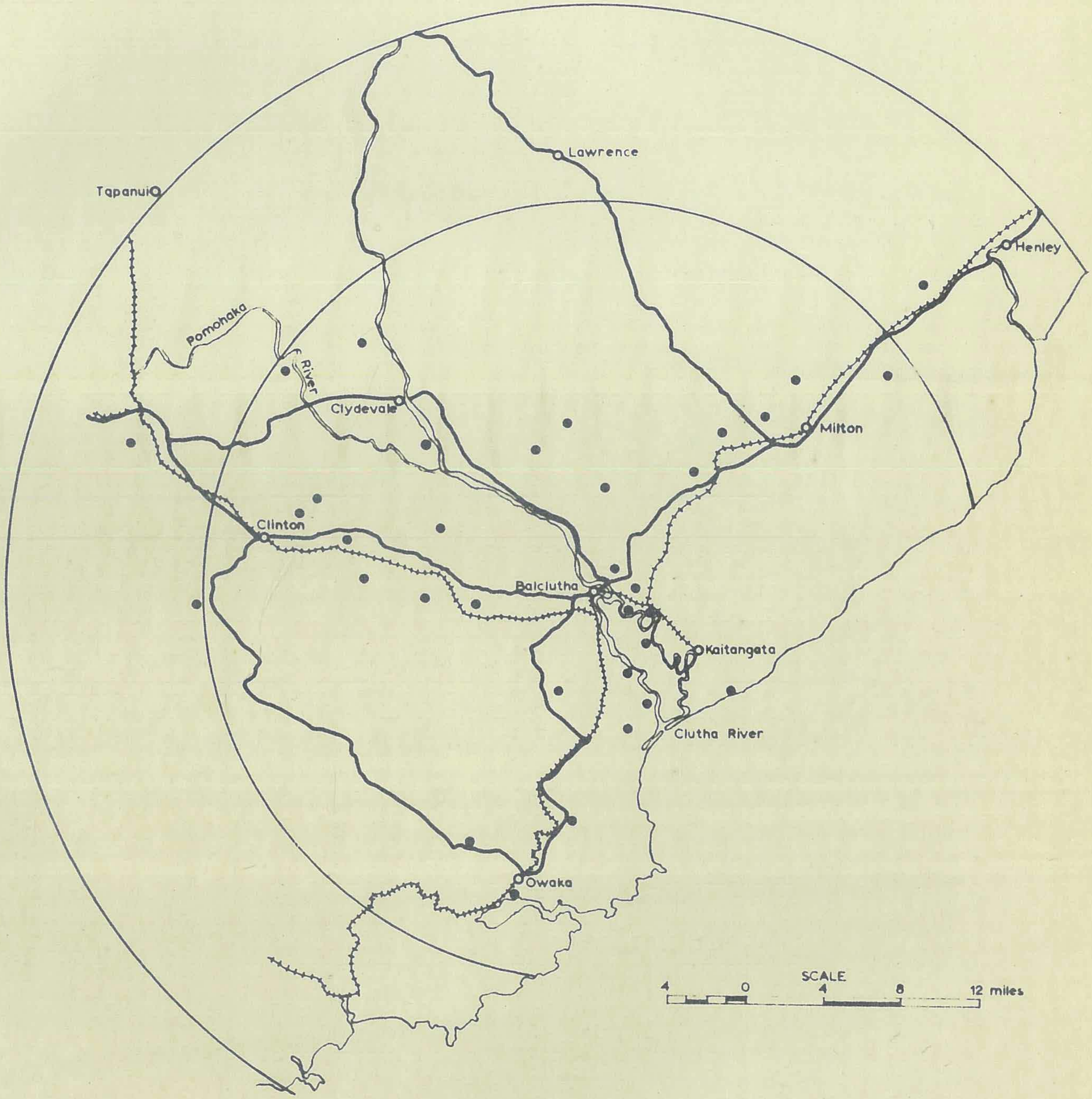
(1) Survey methods and techniques are not discussed except where they are pertinent to the present study. For a general discussion, the interested reader is referred to: Wesney, D., "A Study of the Financial Returns to Process Pea Growers in Hawkes Bay", Vol. I, pp. 5-64, Unpublished Masters Thesis, Massey University of Manawatu, 1964.

Fig 5.1 THE LOCATION OF THE SURVEY FARMS



optimum adjustments to these changes. Candler, in discussing technological change in relation to Farm Management Research, has said,(2)

> "The attitude to changing technology determines the sort of problem that will be tackled. Thus the research worker who is interested in studying adjustments to a given technology will look for an area of uniform soil type, farm size and farming system so that the "between farm" differences will be a minimum. The research worker interested in adjustment to changing technology will attempt to foresee a new farming practice which will be profitable and have a major impact on farm organisation. If the impact is on an area of different soil types and farm sizes this makes the analyses correspondingly more difficult, but not necessarily less worthwhile."

Sugar beet culture is a possible new farming practice which may be profitable and if grown intensively would have a major impact on farm organisation. Where Farm Management research is motivated by this desire to determine optimum adjustments to a change in technology, at the farm level, then farmers who have made or who are interested in the change should be interviewed.

A significant feature of this study is that it is examining the possible impact of an entirely new crop. Since sugar beet has never been grown commercially in South Otago, information at the farm level is restricted to farmer opinion. Few farmers have made an intensive study of the crop and most are probably not aware of its special husbandry needs. Although there is general interest in sugar beet throughout the district, detailed technical information has not been available to farmers.

A further factor of major importance is the differences in farming systems, soil types and contours within the area. This diversity makes some form of district stratification necessary.

These considerations, together with the limitations of time and resources made it necessary to have a purposive selection of farms so that the farmers interviewed would have some knowledge of, and interest in, sugar beet. This

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(2) Candler, W.V., "Production Economics and Problems of Animal Production", Proc. of the N.Z. Soc. of Animal Production, 22: 143-4, 1962.

method of selection inevitably leads to bias in the sample.[3] In this instance the sample is probably biased towards the more progressive farmer - the one who is interested in new innovations and is willing to try out new ideas. However, these innovators in any district are the important individuals to study for it is from the experiences of such farmers that new ideas are formulated (or first tested on a farm scale) proved and then adopted or rejected by others.

The economic position disclosed by the sample probably, but not necessarily, indicates a more prosperous situation than actually exists in the district as a whole.

Since one of the main purposes of the farm survey was to select suitable case farms for study and not to conduct a statistical analysis of the survey results, the problems of bias in the sample are not very important. A random survey of farms can usefully be made where it is necessary to "discover" innovating farmers but this should not often be necessary, because Farm Advisory Officers, personnel of commercial firms and leading farmers all have a knowledge of innovations going on in their areas. A small number of randomly selected farms can, however, be used as "bench-marks" with which to compare farms using a new technology. This comparison is not possible in the present case because sugar beet is not being grown commercially at present on any farm. Thus random survey procedures were not used at all in this study.

5.2 THE METHODS USED

Three individuals were each asked to provide the names of 40 farmers who were known to be interested in sugar beet. Those asked were:

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(3) Karmel, P.N., "Applied Statistics for Economists", Pitman, Melbourne 1959, p.125.

1. The Farm Advisory Officer, Department of Agriculture, Balclutha.
2. The Farm Economist, Department of Agriculture, Dunedin.
3. The Secretary of the South Otago Sugar Beet Investigation Company.

From these lists selections were made by taking names, preferably common to the lists, to give a reasonable geographical coverage of the possible beet growing areas. Most of the farmers interviewed had attended the meetings held in the district and had given the subject some consideration. Many had grown trial plots of beet on their farms and had observed its growth over one complete season. Of those farmers contacted almost all were willing to be interviewed and detailed physical and financial data could have been obtained from approximately 50 per cent of the respondents.

A questionnaire was designed primarily to provide input-output data, production possibilities and restrictions for linear programming analyses and to assess the farm management practices used in the district. This questionnaire was tested in March 1963 on five farms. The test showed that it would be too time consuming to attempt to collect detailed cost information from individual farmers. Modifications were made to the survey questionnaire and emphasis placed on physical input-output data and labour inputs. Most of the essential cost and price information was obtained from commercial firms, Government Departments and published price lists. The amended questionnaire was used for the main survey carried out in June 1963 when a further 29 farmers were interviewed.(4)

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(4) It may be noted here that detailed information was only collected where it was readily available. Since the purpose of the survey was to select suitable farms for detailed study, no attempt was made to fill up the complete questionnaire where either data was difficult to obtain or the farmer was reluctant to supply it.

Owing to the difficulties inherent in the concept of the "average" or "typical" farm(5) as constructed from aggregated data as well as the factors mentioned in section 5.1, "case" or actual farms have been selected for intensive study. The criteria for selection were:

(a) That adequate physical and financial records were available.

(b) That the farmer was willing to disclose the relevant records.

(c) That the management systems in broad outline appeared representative of the locality and soil type concerned.

The use of a small number of case farms does not allow detailed inferences to be made about the region as a whole. Farmers and their advisers should, however, be able to make the necessary changes of detail to the "case farm" data to make it conform with a particular farm, and then budget a useful result. General inferences based on the survey data, combined with the judgement of the investigator are possible and indeed essential, but the reader and the analyst should realise that interpretative judgement is one of the bases of this inference. As more case farm results become available, inferences can be made with increasing confidence.

5.3 THE SURVEY RESULTS

The survey shows the two broad farming systems at present used in the area. It also shows a very diverse farming pattern within the broad groupings which makes the definition, in detail, of an average or typical system impossible. This is to be expected in a district with such a wide range of soil types and contours.

Dairying predominates on the rich, fertile soils in the Stirling-Kaitangata-Inchclutha-Paratai districts. Substantial acreages of fodder crops are grown and

(5) Candler, W.V., and Sargent, D., "Farm Standards and the Theory of Production Economics", Jnl. of Agric. Econ., 15 (2): 282-290, 1962.

the feeding of them commences in April and may continue until October. Some potatoes and a little wheat are grown. Some of the larger properties are run as intensive fat lamb enterprises with potatoes as a cash crop. There is an increasing demand for winter milk from Dunedin and many dairy farmers have a small town milk quota over the winter months.

The remainder of the region is devoted to fat lamb farming with the associated fodder crops of swedes and choumoellier. Wheat is being grown in increasing amounts in the lower rainfall areas, but not in the Owaka Valley where the relatively high summer rainfall makes harvesting very difficult. Crops of barley, oats, linseed, ryegrass seed and clover seed are occasionally grown but are all of minor importance. The major products are wool, fat lambs and, increasingly, wheat.

Many sheep farmers are experimenting with new rotations, especially those who have recently started growing wheat. The dairy farmers have a stabilised rotation but cropping sequences very from farm to farm. Despite the generally accepted necessity for winter root crops, two of the farmers visited were using all grass systems. One, a sheepfarmer, has grown wheat for the last three years but no fodder crops and relies on saved grass and hay for winter feed. The other, a dairy farmer, buys hay and makes large quantities of grass silage.

The small sample size and the diversity within the sample make it impossible to present a comprehensive analysis in a concise and meaningful way. Some simple tabulations are given below which broadly describe the survey farms. Detailed descriptions of the case farms are given in Chapter 7.

5.3.1 Type of Farming

The survey farms can be classified in terms of the livestock carried as follows:

Sheep and cattle	17
Sheep only	10
Dairy cattle only	5
Dairy cattle and sheep	2
Total	34

5.3.2 Capital Position

Thirty of the farmers stated that they would have no difficulty in financing the purchase of new plant and machinery for sugar beet growing. They all had substantial cash reserves and few liabilities.

Three farmers had recently purchased their properties and were developing their farms as rapidly as finance would permit. One of these farmers thought that a small acreage of sugar beet would provide additional urgently needed cash for further development.

One dairy farmer with only a small area of good land had large liabilities and would only grow the crop if it was handled by contractors.

5.3.3 Farm Incomes

On farms where the annual accounts were made available, farm profits before tax were in the range £1,450 to £6,000. Only one farmer considered his farm income too low and he was thinking of selling his small sheep farm and buying a larger property with more potential. The other farmers said they did not feel the need for additional enterprises to increase farm income. Sheep farmers had increased carrying capacity and had grown more wheat over recent years and these measures had maintained farm income in spite of falling meat and wool prices. All considered that with increased rates of fertilizer application and subdivision they could increase production further. The two main reasons given for not exploiting this potential were the shortage of suitable labour and the high rates of taxation the increased income would attract.

Dairy farmers thought that carrying capacities could not be increased very much further without large capital investment in animal housing facilities. There may, however, be scope for cheaper methods of production by growing fewer crops and relying more on pasture. The town milk quota has helped maintain the incomes of some dairy farmers in recent years.

The above picture of a relatively comfortable situation obtained, even before the recent rise in wool prices.

5.3.4 Farm Size

The survey farms are classified according to acreage in Table 5.1.

TABLE 5.1

FARM SIZE

Acreage Range	Sheep Farms	Dairy Farms	Mixed Farms	All Farms
0- 250	1	5		6
251- 500	12		2	14
501- 750	6			6
751-1000	3			3
1001-1250	2			2
1251-1500	2			2
More than 1500	1			1
Totals	27	5	2	34

Table 5.1 shows that 20 farms are in the range 0-500 acres and 29 farms in the range 0-1000 acres.

5.3.5 Labour Employed

The labour position on the survey farms is extremely complex and depends on the type and intensity of farming and the family situation. Some owners work only part-time on the farm, having sons who are taking over increasing responsibilities and in other cases labour is shared between two farms.

Casual labour is used by all farmers, but in widely different amounts. Many dairy farmers near Balclutha employ school boys for hand weeding and thinning swede and mangold crops. Contractors are employed extensively for harvesting, spraying, shearing and fertilizer and lime sowing. All farmers do their own cultivation work and a few employ an additional tractor driver when necessary.

All farmers said that there was a serious shortage of labour in the district. Any sudden and simultaneous demand by farmers for additional labour could not be met. The main sources of labour were thought to be freezing workers in the off-season, part-time farmers, neighbouring farmer's sons and school boys.

The units of permanent labour available (including the owner) on the survey farms are shown in Table 5.2.

TABLE 5.2

PERMANENT LABOUR AVAILABILITY

Units of Labour*	Number of Farms
1.0	7
1.5	3
2.0	10
2.5	4
3.0	7
3.5	1
4.0	1
6.0	1

* One labour unit is equivalent to one adult male permanent worker.

Note: Sixteen single men and twenty-one married men (including six on the one very large farm) are employed.

5.3.6 Plant and Machinery

Most farmers owned or had shares in a full range of cultivation and grass cutting machinery. Several had shares in combine harvesters. Two farmers were installing large capacity grain driers and grain storage silos. The number of tractors per farm is shown in Table 5.3.

TABLE 5.3

NUMBER OF TRACTORS PER FARM

Number of Tractors	Number of Farms
1	6
2	14
3	11
4	3

In most cases the second or third tractor was an old model which had not been traded in when a new one had been purchased. These tractors are only used at peak periods and may not be capable of withstanding sustained hard work.

5.3.7 Livestock and Cropping Policies

Livestock and cropping policies varied markedly from farm to farm. They depended upon rainfall, soil type, soil fertility, contour and the preferences of the owner.

The seven farmers who kept dairy cows reared their own herd replacements and four of them used the Artificial Breeding Service of the New Zealand Dairy Production and Marketing Board. Two farmers ran Jersey cows, while the remainder had Friesian herds.

The livestock replacement policies on sheep farms included purchasing aged ewes, purchasing two-tooth ewes and retaining ewe lambs for flock replacements. All of the survey sheep farms ran Romney ewes only. Cattle were kept by 16 sheep farmers. A small breeding herd was maintained on 14 farms, while steers were fattened on two farms. Cattle were not kept on 11 farms.

The fodder crops grown were mainly swedes on sheep farms and some, or all, of swedes, mangolds and choumoellier on dairy farms. In addition, rape, kale, greenfeed oats, greenfeed barley, ryecorn and lucerne were grown on one or more farms. As noted in section 5.3, fodder crops were not grown on two farms.

Wheat was the main cash crop, with some potatoes on the more fertile land. Oats, barley, linseed and grass and clover seed were also harvested on an occasional property.

5.3.8 Management Changes Over the Last Five Years

Thirteen farmers had either commenced to grow wheat or had substantially increased the acreage grown, three were engaged in farm development projects, two had changed to an all grass system, while sixteen had made no major changes.

5.3.9 Management Changes Contemplated

Few farmers had given future changes, except sugar beet production, serious thought. Further increases in wheat growing were considered feasible, especially since the introduction of efficient wheat driers. Some with suitable soils had considered potatoes, but the ability of the market to absorb increased supplies was a limiting factor.

Ten farmers were interested in increasing cattle numbers and one was actively investigating the feed-lot system of fattening using home grown grains. Provided beef prices remain favourable, these men consider that cattle breeding on the steeper country and fattening on the richer land has considerable potential for expansion.

5.3.10 Farm Topography and Sugar Beet Acreage Offered

Farmers were asked for topographical details of their farms and how many acres of sugar beet they would be willing to grow with the information and experience they had in June 1963. Table 5.4 has been compiled from the answers given.

TABLE 5.4

CONTOUR CHARACTERISTICS OF THE SURVEY FARMS AND ACREAGE OF SUGAR BEET OFFERED

	Total (acres)	Average Per Farm (acres)
Surveyed farm area	20,760	610
Area flat	3,776	111
Area headable	15,022	442
Area suitable for sugar beet	10,441	307
Area offered*	435.5	12.8

* Of the 34 farmers, four did not know how much sugar beet they would offer to grow, three would not grow any, and one would only grow the crop for a year or two to help establish the factory.

Table 5.4 shows that only two-thirds of the headable area would be suitable for sugar beet. Farmers considered that sugar beet machinery could not operate on the steeper and more broken country that is negotiable by header harvesters.

Table 5.4 also shows that very limited areas of beet would be grown on these farms at the time of the survey. This lack of response was probably due to two main factors. Firstly, that farmers considered that their present incomes were reasonably adequate and, secondly, a lack of knowledge of the technical requirements of the sugar beet crop.

5.3.11 Cultural Conditions for Sugar Beet

No difficulty was anticipated by any farmer in having the seed bed prepared by late September or early October. However, many farmers thought that harvesting should be completed by late autumn or early winter so that possible difficulties, due to wet soil conditions, would be avoided. The months by which most of the harvesting should be finished is shown in Table 5.5. Harvesting may be possible in subsequent months in some years, but could be seriously interrupted by excessive winter rain.

TABLE 5.5
LATEST MONTH FOR EFFICIENT HARVESTING

Month	Number of Farms
March	1
April	12
May	16
June	4
No restriction	1

Table 5.5 indicates that harvesting may be difficult on 13 farms from 1 May and on 29 farms from 1 June.

5.3.12 Gross Margin[6] Required from Sugar Beet

Farmers were asked whether they could estimate the gross margin they would require from sugar beet relative to wheat. This was difficult for them to answer accurately because many farmers had limited knowledge of the requirements of sugar beet production.

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(6) Gross Margins are discussed in Chapter 6. For present purposes, it is sufficient to define the Gross Margin as Gross Revenue minus Variable Costs.

TABLE 5.6

GROSS MARGIN REQUIRED FROM SUGAR BEET (PER ACRE)
RELATIVE TO WHEAT (PER ACRE)

Relative Gross Margin Per Acre	Number of Farmers
Do not know	2
A similar return	4
A higher (unspecified) return	5
£5 per acre higher	2
£10 per acre higher	15
£15 per acre higher	3
£20 per acre higher	3

Table 5.6 shows that, even for the small areas offered, 28 farmers wanted a higher gross margin for sugar beet than for wheat.

5.3.13 Use of Tops and Crowns

Sheep farmers considered that early harvested beet would provide tops at a time when they would have little use for them except possibly for fattening late lambs. The later tops would provide early winter feed for ewes and may substitute for some swedes. They could be fed to cattle at all times. Sheep farmers discounted the value of the tops; small tonnages could be used but any surplus would be ploughed in.

Dairy farmers said they could make good use of the tops, substituting them for choumoellier in the autumn and for swedes in the winter. Any surplus could be made into silage for spring feeding and substitute for mangolds.

5.3.14 Use of Pulp

Stock feeding concentrates were not used extensively on any of the survey farms. Sheep nuts were purchased by some farmers, mainly those with stud flocks, but these did not exceed two tons per farm each year.

Farmers did not think they would use the pulp unless it was very cheap and could be easily fed to stock in the paddock. Those who were interested in stall feeding cattle thought it may provide a source of cheap feed and one, who is close to the proposed factory site, thought he could utilise large quantities of wet pulp, fresh and ensiled.

5.4 SUMMARY

Most of the survey farms are in a strong financial position and are providing returns which are satisfactory to the owners. There is said to be no surplus labour on these farms, which is felt to be one factor limiting further increases in output, the other being the high incidence of taxation on increased earnings. Plant and machinery inventories are adequate for present purposes. Some investment is being made in grain harvesting, drying and storage equipment.

No radical management changes have been made over the last five years on the majority of farms, except the two that have changed to an all grass system. Carrying capacities have been rising and there has been a gradual move into more cash cropping.

Farmers consider that diversification prospects are limited and see sugar beet as an enterprise with an assured local market which could help stabilise farm income if the prices of export products fall. They are only willing, at present, to consider small acreages which would not disturb their basic farming policies. Sugar beet, therefore, has to fit in around existing enterprises which makes the use of the by-products difficult, especially on sheep farms. On dairy farms the tops could be used readily but organisational changes would be required to utilise the pulp.

Farmers close to the proposed factory have recognised their advantage and may be willing to set up specialised feeding facilities provided such a venture was shown to be profitable. If this was done, large quantities of wet pulp could be used, both fresh and ensiled.

Many farmers insist on early harvesting but they do not foresee planting problems in spring provided mechanization is complete. It would appear that a gross margin substantially higher than wheat would be required to induce farmers to grow even small acreages.

It should be noted that the opinions expressed by the survey farmers were those held in June 1963. Continuing trial work is providing more data and farmers views may be modified as they evaluate new information. Especially if lamb and wool prices fall, they may be willing to consider the major organisational changes which would be necessary to ensure the efficient use of the by-products of beet sugar production.

CHAPTER 6

THE ESTIMATION OF GROSS MARGINS

The major objective in the evaluation of alternative farming practices is to help farmers to raise their net farm incomes. Attention is directed towards finding new combinations of farm enterprises, consistent with the resources available, which will increase profits. In the short run resources on a farm are fixed and the various enterprises must compete for their use. Alternative farm plans are examined until the one which most profitably uses the available resources is obtained.

The techniques of budgeting(1) and linear programming(2) can be used to evaluate alternative farm plans. Budgeting allows a step by step approach to (but not necessarily the attainment of) the most profitable farm plan. If, however, the problem can be formulated in a manner appropriate for the use of linear programming <u>the</u> most profitable farm plan can be determined, given the resource and other restrictions.

One essential requirement in the use of either technique is the calculation of enterprise gross margins. The problems encountered in these computations and also the gross margin for sugar beet are discussed below.

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(1) Bradford, L.A., and Johnson, G.L., "Farm Management Analysis", Wiley and Sons Inc., New York, 1953.
Heady, E.O., and Jensen, H.R., "Farm Management Economics", Prentice-Hall Inc., pp. 91-119, 1954.

(2) See Chapter 7.

6.1 GROSS MARGINS

A farmer may be viewed as a manager with certain resources of land, labour and capital. Economic theory assumes that his aim is to use these resources to gain the maximum profit. In reality, the farmer may have other objectives. He may place importance on activities outside the farm such as service on public bodies, he may take a pride in breeding pedigree stock even though this results in lower profits, or he may be content with a low income provided he can have a less strenuous life. In the analyses that follow personal considerations are largely ignored and it is assumed that the aim is maximum profit from the resources available. If the individual farmer has other aims he can build them into his own plans.

A farm can be regarded as a group of enterprises based upon certain fixed resources of land, labour and capital and co-ordinated by the management of the farmer. The costs associated with these enterprises and resources may be placed in two main categories, variable costs and fixed costs. The costs of the direct inputs of each enterprise are the variable costs. These expenses, such as fertilizer, seed and fuel, change with the level of output. Fixed costs, however, are those of an overhead nature which do not change with the level of output. Rates, building depreciation and interest payments are examples of fixed costs which must be met even if nothing is produced.

Variable costs may be subdivided into "observable" and "imputed" variable costs. "Observable" variable costs are those which can be attributed directly to a particular enterprise. Examples are fertilizer, seed and spray materials. "Imputed" variable costs are those which must be allocated to each enterprise because the actual costs cannot be determined directly. Examples are fuel costs and machinery repairs and maintenance.

The difference between the value of the output of an enterprise and its variable costs is termed the gross margin for that enterprise. This gross margin represents the contribution of the enterprise towards paying off the fixed costs of the farm. Any difference between the total of the gross margins of all the enterprises and fixed costs is the profit or loss resulting from the given farm plan. This profit or loss is also called the net farm income.

For any given level of fixed costs, the larger the total gross margin from all enterprises, the larger the net farm income. This is the fundamental principle underlying all farm planning. Farm planning is concerned with the choice of enterprises in relation to the available resources of the farm and the successful plan balances the returns to each of the fixed resources, i.e., attempts to equate the marginal value product of each resource with its marginal cost.

6.2 CALCULATION OF GROSS MARGINS[3]

If the farmer has kept sufficient records the variable costs can be allocated immediately to the individual enterprises.

Few farmers keep comprehensive records, but nearly all the data required should form the background knowledge that a good farmer has about his farm. As long as details of the physical inputs and outputs and techniques used can be obtained gross margins can be calculated because cost and price information can be secured from commercial firms and published price lists. A detailed analysis of the individual farmer's original invoices, statements and cheque books would yield the information but this would be unacceptable to most farmers and very time consuming for the analyst.

The allocation of fuel costs, tractor and machinery repair and maintenance costs present considerable difficulty. Fuel costs could be allocated to the various enterprises so long as the appropriate records had been kept but the

(3) Wesney has discussed the problems of calculating gross margins exhaustively but the reader should note that his terminology differs from that used in this study. Wesney's use of the term "net revenue" is equivalent to the term "gross margin" used here. See, particularly, p.141 of the reference below.
Wesney, D.A. (1964), <u>op. cit.</u>, pp.65-118 and p.141.

allocation of repair costs can only be made proportionately, usually in terms of the time spent on each enterprise. (If the machine is specialised for one enterprise then no problem arises.) This method is arbitrary and takes no account of special circumstances which may cause greater wear and tear when the same machine is used under different conditions. For example, the wear on cultivation implements depends to a great extent on soil conditions and some adjustments should be made for extreme variations from normal.

Since farmers do not usually keep records that enable fuel and repair costs to be allocated directly, the author has allocated these costs to the various enterprises in proportion to the hours of work required per acre. That is, the variable costs for machinery use have had to be imputed as they are not available from directly observed data.

Current data for assessing these costs is extremely meagre in New Zealand. The Department of Agriculture recognised the need for more accurate data when it initiated the Tractor Recording Scheme during the 1947-48 season in Canterbury.[4] A scheme covering the whole country was commenced in 1950 and some results published in 1956.[5] The scheme seems to have lapsed since then due to the difficulty of recruiting sufficient farmers who were willing to keep detailed records over the operating lives of their machines.

McLay and Garrett[6] have published figures based on the work of the Department of Agriculture in Canterbury. Tractor fuel and repair costs have been calculated from data in their publication, given in Table 6.1, using 1962-63 costs and prices.

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(4) MacPherson, R.I.C., "Survey of Tractor Operating Costs on Farms", N.Z. Jnl. of Agric., 86: 323.

(5) MacPherson, R.I.C., "Tractor and Farm Operating Costs", N.Z. Jnl. of Agric., 93: 447.

(6) McLay, A.K., and Garrett, H.E., "Implements and Cultivation", Canterbury Agricultural College, 1959, pp. 53-64.

TABLE 6.1

TRACTOR, FUEL, OIL AND GREASE CONSUMPTION AND REPAIRS AS A PERCENTAGE OF INITIAL COST

Group	Rated D.B.H.P.*	Petrol (gals./hr.)	Diesel (gals./hr.)	Lub. Oil (pints)	Grease (lb.)	Repairs (% of cost)
1	20-25	1.3	-	0.18	0.02	65
2	20-25	-	1.1	0.18	0.02	50
3	25-30	1.5	-	0.20	0.02	60
4	25-30	-	1.3	0.20	0.02	50
5	30-35	-	1.5	0.20	0.03	45
6	30-35	-	1.6	0.25	0.10	70

* Draw-bar Horse Power.

Source: McLay, A.K., and Garrett, H.E., "Implements and Cultivation", Tables I and II, p.55, and Table III, p.56.

Tractors were divided into six groups according to their rated draw-bar horse power and the type of fuel used. Group 6 is made up of crawler tractors, while groups 1 to 5 are wheel tractors.

The last column gives maintenance, repair and replacement costs on the basis of a percentage of the initial cost of the tractor. No allowance is made for farm labour involved in general maintenance work. The total cost, when spread over the "generally accepted" economic life of these tractors of 10,000 hours gives an average hourly figure.

The calculation of implement repairs and maintenance costs is also difficult. McLay and Garrett's figures have been used supplemented from estimates made by Culpin.(7) Culpin emphasises that his estimates should only be used where reliable figures are not available. His estimate includes a charge for farm labour and adjustments have been made to eliminate this.

(7) Culpin, C., "Farm Mechanization Management", Crosby and Lockwood and Son, (London), 1959, p.213.

Table 6.2 shows the estimates used for all calculations in this study.

TABLE 6.2

IMPLEMENT REPAIRS AND MAINTENANCE COSTS PER HOUR

Implement	Cost per hour
	s. d.
Plough (double furrow)	1 - 0
Disc (8 ft. tandem)	9
Grubber (13 tine)	9
Harrows (5 leaf)	3
Roller (9 ft. Cambridge)	4
Drill (15 coulter)	3 - 0
Mower (6 ft.)	1 - 4
Siderake	1 - 0
Scuffler (4 row)	9
Ridger (4 row)	1 - 0
Binder	2 - 0
Topdresser	1 - 0
Sprayer	6
Sugar beet harvester (complete 1 row)	5 - 0
Dutch Harrow	9
Scrubber or clod crusher	3
Precision drill (4 row)	1 - 6
Mechanical thinner (4 row)	9
Steerage Hoe (4 row)	1 - 6
Trailer (hydraulic tip)	3
Potato moulder (2 row)	9
Potato harvester (1 row)	3 - 0

The procedure for calculating gross margins may be summarised as follows:

1. Estimate the gross revenue per acre (or per stock unit) for the enterprise. For forage crops this will be zero.

2. Estimate the observable costs for the enterprise.

   (a) For crops these may be:
   - (i) Seed
   - (ii) Fertilizer
   - (iii) Sprays
   - (iv) Contract charges
   - (v) Casual labour
   - (vi) Freight and cartage
   - (vii) Sundries

   (b) For livestock they may be:
   - (i) Stock purchases
   - (ii) Shearing charges
   - (iii) Milking shed or wool shed expenses
   - (iv) Animal health charges
   - (v) Freight and cartage
   - (vi) Sundries

3. Estimate the imputed costs for the enterprise.
   - (i) Tractor fuel, oil and grease per acre plus tractor repairs and maintenance per acre.
   - (ii) Implement repairs and maintenance per acre.

The sum of the observable costs and the imputed costs subtracted from the gross revenue gives the gross margin.

The fixed costs can be taken from the financial accounts of the farm as long as care is taken to exclude any variable costs that may have been included. For example, casual labour is usually included in total labour costs in the accounting procedure, permanent labour being a fixed cost.

To enable labour and machinery requirements and capabilities to be analysed additional physical information is required. A record of monthly labour requirements for each crop has been obtained by means of a detailed statement of all tasks carried out, the rate of work, the number of men employed and the period of time over which it is possible to carry out the task. The figures have been obtained for a normal or average season. This is relatively straightforward for cropping enterprises where rates of work are well known and do not fluctuate markedly, although the total amount of work required may vary. This is especially so with cultivation which may have to be repeated several times if weather and soil conditions are unfavourable. With livestock, however, the rates of work depend upon the circumstances and conditions at the time, particularly for such tasks as lambing and shepherding. Further, during peak periods or adverse conditions the farmer will increase his labour "supply" by working extremely long hours. Thus labour requirements for many tasks can only be estimates of normal practice. It should be recognised that some of the numerical values used are subject to wide variation.

An inventory of the major items of machinery and their working capacity is also required.

6.3 GROSS MARGIN FOR SUGAR BEET

The estimates and calculations for sugar beet are now discussed in detail to illustrate the methods used and to list the assumptions made.

The machine and labour hours required per acre are given in Table 6.3. The last column showing labour hours per acre has been derived from the machine hours column by adjusting the figures upwards to make allowance for time spent lubricating, setting and preparing the machine for work, tractor maintenance, and time spent travelling to and from the paddock.(8)

In constructing the table, the following assumptions have been made.

(a) Sugar beet follows a cereal crop and early ploughing is possible.

(b) Any necessary levelling has been done before sowing the previous crop.

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(8) McLay and Garrett, op.cit., p. 58.

(c) A deep digging short mould-board plough is used to bury any surface rubbish and to shatter the furrow so that after winter weathering only a minimum of seed-bed cultivation is necessary.

(d) The crop is thinned mechanically and weeded chemically so that hand work is not required.

(e) All operations except harvesting can be carried out by one man. Three men and three tractors are required for lifting.

(f) All beet is transported by road to the factory but trucks do not enter the beet paddock. Tractors and trailers are used to cart the beet to a suitable site for stockpiling adjacent to the beet paddock. They are then loaded into trucks by a front-end loader mounted on one of the transporting tractors. Half the crop is dealt with in this way while the remainder has to be clamped, preferably on a concrete apron, on the roadside and is loaded through a cleaner loader. If harvesting and loading from the clamp continue together an additional man and tractor will be required. This should not be necessary, for direct loading is presumed to be possible when harvesting is possible. The need for clamping arises because a supply of beets has to be built up to meet delivery permits when harvesting is impossible, after rain.

(g) The tops and crowns are wind-rowed by the harvester and break fed to stock, after wilting. This implies that care must be taken to see that the tractors and trailers carting the beet travel over the paddock without damaging or soiling the tops.

(h) The expected average yield is 17.5 tons of washed and topped beet per acre. The dirt tare is 8 per cent.

(i) The price paid for washed beet is £5 per ton delivered to the factory.

(j) Distance from the factory is 20 miles.

(k) Two permanent labour units and three tractors are available.

TABLE 6.3

MACHINE AND LABOUR HOURS REQUIRED FOR ONE ACRE OF SUGAR BEET

Operation	Date	Once Over (hrs/acre)	Strokes	Machine (hrs/acre)	Labour (hrs/acre)
Plough	April-May-June	1.00	1	1.00	1.210
Cultivation (light)	July-Aug.	0.25	2	0.50	0.578
Topdress	Sept.	0.25	1	0.25	0.303
Harrowing and crushing	Sept-Oct.	0.25	3	0.75	0.829
Drilling and pre-emergence spray	Sept-Oct.	1.00	1	1.00	1.320
Thinning	Oct-Nov.	0.50	2	1.00	1.320
Hoe (1st time)	Oct-Nov-	1.00[a]	1	1.00	1.155
Hoe (2, 3, 4 times)	Dec.	0.50	3	1.50	1.733
Aphid spray	Nov-Dec.	0.20	1	0.20	0.253
Harvest (1 man)	April-May-June	4.00	1	4.00	4.620
Carting (2 men)	April-May-June	8.00	1	8.00	8.400
Loading from clamp (50% of crop, 20 tons per hour)	June-July	-	-	0.33	0.382
Totals				19.53	22.103

(a) A faster rate of work is possible at the second and subsequent hoeings as the hoe travels in the "track" left at the first hoeing and the beet rows are more easily seen.

The following budget, giving the gross margin per acre for sugar beet, can now be constructed.

	£	£
Receipts:		
17.5 tons @ £5 per ton		87.500
Variable Costs:		
Seed: 5 lbs. per acre @ 6/- per lb.	1.500	
Lime: 5 cwt. per acre @ £3 per ton spread (share)	0.750	
Fertilizer: (£) 2 cwt. boronated super 1.210; 4 cwt. 33⅓% potassic super 3.010; 2 cwt. Nitro lime 3.100; 8 cwt. per acre (freight included)	7.320	
Pre-emergence Spray: Murbetex at medium rate, 21 in. rows 7 in. band (estimate)	5.000	
Aphid Spray: (Estimate)	2.000	
Cartage: 17.5 tons of beet; 1.4 tons of soil; 18.9 tons @ 9d per ton mile (20 miles)	14.175	
Casual Labour: 4 hours @ 10/- per hour (required at harvest)	2.000	
Tractor Costs: 19.53 hours @ £0.232 per hour	4.531	
Machine Costs:	1.711	
		38.987
Gross Margin:		48.513

This calculation assumes very good husbandry conditions for the crop and skilled management throughout the season. It presents an idealised version which can be used as a basis from which to derive realistic values for any particular situation.

6.4 FEED PRODUCED

Production of tops and crowns is assumed to be 90 per cent of root yield. Utilization is 60 per cent, giving 9.45 tons of tops actually consumed by stock.

6.5 OVERSEAS COSTINGS

The costs and returns from sugar beet are assessed annually in most countries where the crop is grown. In Britain the Farm Management Survey Farms provide data for the numerous published reports.(9) These figures have little relevance to the present study, because they are based on different working conditions, methods and costs. Costs and returns must be derived for the conditions and circumstances that apply in South Otago.

The most significant feature of these overseas costings is the wide range of results on individual farms. Hyde(10) reported on 54 farms and found that the net (not gross) margin ranged from a profit of £58.83 per acre to a loss of £18.04 per acre. These wide differences were attributed mainly to variations in yield, caused primarily by different standards of cultural practice on different farms.

6.6 GROSS MARGINS FOR OTHER ENTERPRISES

Gross margins have been calculated for all crops, grazing and livestock enterprises in a manner similar to that described for sugar beet for each case

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(9) See for example,
Cam, B.M., "Farm Planning Data, 1962", and Nix, J.S., "Economics of Producing Sugar Beet, 1957", Report No. 52, both published by the Farm Economics Branch, School of Agriculture, Cambridge.

(10) Hyde, D.C., "Sugar Beet Costs and Returns from the 1961 Crop", Dept. of Economics, Univ. of Bristol.

farm. The present management practices, yields and prices obtaining on each farm have been used so the margins derived are different for each case farm. The figures obtained are detailed in Appendix II.

CHAPTER 7

A LINEAR PROGRAMMING ANALYSIS

Linear Programming is a mathematical technique, based on the properties of matrices and is included in the broad group of analytical methods generally known as Activity Analysis. It is a method of comparing the economics of alternative production processes with the aim of selecting the most profitable combination. The theory and practice of the method has been discussed by many authors (see references) so only a brief discussion is presented here and attention is concentrated on the interpretation of the results.

7.1 SOLUTION OF NORMATIVE PROBLEMS(1)

The term normative is used in economics to describe analyses which explain what course of action ought to be taken by an individual, business unit, district or some other economic sector when the objectives are clearly defined and the conditions and restrictions surrounding the action are enumerated. If a farm problem is defined in terms of profit maximization for an individual farmer and the quantities of resources and the restrictions on their use exhaustively determined, then a plan indicating the products to be produced and the techniques to be used can be specified. But the solution obtained is strictly in terms of the objective of maximum financial profit and the stated resource constraints.

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(1) Heady, E.O., and Candler, W.V., "Linear Programming Methods", Iowa State University Press, Ames, Iowa, U.S.A., 1960, pp. 8-9.
and
Heady, Earl O., et. al., "Agricultural Supply Functions", Iowa State University Press, Ames, Iowa, U.S.A., 1961, pp. 16-19.

The normative solution does not explain or predict what action a farmer will take. If, however, all the restrictions that an individual farmer actually imposes on his plans could be quantified,[2] they could then be included in the statement of the problem, which is then solved with the added constraints. The difference in income between the two normative solutions provides a measure of the cost of deviating (in terms of income foregone) from the profit maximizing plan.

In contrast, the term <u>positive</u> is used to describe analyses which describe phenomena as they exist, rather than what they "ought" to be. In the case of sugar beet, a linear programming analysis may be used to derive a normative supply function while a regression analysis based on time series may be used to derive a positive supply function. The former would indicate plans which would maximize profits as prices change while the latter would describe and predict how farmers actually do respond to price changes. The results of the two analyses would probably differ considerably.

The distinction between these two forms of analysis should be recognized and appreciated by those who wish to use and interpret studies based on these procedures. (A positive analysis for sugar beet in New Zealand is, of course, impossible since the crop has never been commercially grown here.) The analyses which follow are normative in the sense described above. Even if it is shown that farm plans including sugar beet can increase farm profits substantially it does <u>not</u> follow that farmers generally will be willing to grow the crop commercially.

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(2) For example, three weeks hunting in Fiordland in May or an unwillingness to work for less than £1 per hour.

7.2 MODEL CONSTRUCTION

Stewart(3) lists the various stages in the construction of a linear programming model as follows:

(a) List the possible activities(4) which are to be programmed.

(b) Calculate the net revenue (gross margin) of each of the activities.

(c) Determine and enumerate the resource restrictions and other limitations, which are to be imposed on the activities. (These may be grouped under the single title of constraints.)

(d) Detail the requirements of the activities for these constraints.

With the exception of sugar beet, only activities at present being used in the district have been included in the three models constructed.

The gross margins of the various activities have been calculated as described in the previous chapter and are shown in Appendix II. Costs have not been imputed to permanent labour or to land. The costs considered are the variable costs resulting from the use of factors which, for practical purposes, are in unlimited supply. Permanent labour and land appear in the problems as constraints. Their value in production has been determined in the programming rather than by the use of some arbitrary accounting values.

Resource requirements and constraints are detailed and discussed for each model in later sections.

7.2.1 <u>A Special Problem: The "Variable Overheads" of Regrassing from Crop</u>

Two methods have been used for taking account of the costs and resource requirements of sowing down new pasture following a cropping cycle.

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(3) Stewart, J.D., "A Study in the Application of Linear Programming to an Oxfordshire Farm", Misc. Studies No. 21, Univ. of Reading, Dept. of Agric. Econ., 1961.

(4) See section 7.5.1.

In sections 7.5, 7.7 and 7.10, activities have been defined as single enterprises. No attempt has been made to define rotations in advance and the costs and resource requirements of regrassing have been regarded as overheads. Now these overheads will vary with the length of the rotation and adjustments to the programmed revenues may be necessary for comparative purposes. Where the programmed solutions have been compared, appropriate rotations have been derived and account taken of the different regrassing overheads involved.

In section 7.8, however, a series of rotational activities have been derived so that regrassing costs and resource requirements could be charged directly to each rotation.(5)

Further, the capital investment in livestock and machinery differs among solutions. Therefore, adjustments have also been made to take account of these differing overhead costs. The plan representing present policy on each farm has been used as a basis for comparison. (See section 7.5.4.)

7.3 LINEAR PROGRAMMING SOLUTIONS

Since perfect divisibility of inputs and outputs is assumed in linear programming, the exact solution may not consist of whole numbers only. Thus the "optimum plan" as given by linear programming cannot always be followed precisely because certain inputs and outputs cannot be broken into fractional units.(6)

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(5) Consideration was given to the construction of a comprehensive model from which rotations could be determined optimally from single enterprise activities. This approach was rejected because of data limitations, particularly data on feed produced by pastures under different systems of management and of different ages. An extensive programme of research into pasture growth and utilization would be necessary in South Otago to provide reliable information.

(6) For example, livestock inputs cannot be included in fractional units and paddock size may dictate the actual acreage of a crop that is possible. The technique of integer programming can be used to ensure an integer solution, but the computational burden this imposes was not felt to justify the greater realism of the results which would have been obtained. See for instance:
Gomory, R.E., "Essentials of an Algorithm for Integer Solutions of Linear Programmes", Bull. of Am. Math. Soc., 64: 275, 1958.
Musgrave, W.F., "A Note on Integer Programming and the Problem of Increasing Returns", Jnl. Farm Econ., 44(4): 1068, 1962.

The exact mathematical solution obtained is optimum for the assumptions made. These assumptions are often over-simplifications of the actual farming situation and render the farm plan an approximate one from a practical viewpoint. However, additional constraints can be added and, provided production information can be obtained in the required detail, the model can be made to reflect very closely the actual farm situation.

Linear programming allows us to explore many facets of a problem. The effect of relaxing restrictions, varying prices and input-output coefficients can be worked out once the basic model has been set up.(7) This is particularly relevant to a study of sugar beet where the lack of data precludes the exact determination of some coefficients and restrictions. Various situations have been explored in the programming analyses which follow.

7.4 PRESENT MANAGEMENT POLICY ON CASE FARM 1

This sheep farm is situated in the Hillend district, 11 miles by road from Balclutha and 7 miles from the nearest railway station. Contour varies from easy rolling to steeply rolling country and there are no significant areas of flat land. The area of the farm is 500 acres and the owner estimates that 250 acres could be harvested with a self-propelled header harvester. A small proportion of the remaining 250 acres could be giant disced and sown to fodder crops but this would only be done if pasture renewal became necessary. The soil is Clydevale silt loam which over-lies a clay pan so that pugging can occur in wet winters.

The highest parts of the farm are 950 feet above sea level and at this altitude snow is likely in July and has been known to remain for up to 7 days in some years. Summer and autumn fogs can create very difficult conditions for

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(7) Heady, E.O., and Candler, W.V., op. cit., and Candler, W.V., and Manning, R., "A Modified Simplex Procedure for Problems with Falling Average Cost", Jnl. Farm Econ., 43 (4): 859, 1961.

cereal and seed harvesting. Erosion is not considered a potential danger by the owner, although exceptionally heavy rain can cause some damage to paddocks of newly sown grass.

The capital position of the farm is sound, there being only a small mortgage liability, so that the purchase of sugar beet plant and machinery could be readily financed. Farm taxable profit has been in the £2,500 to £3,500 range in recent years.

A single man assists the owner and no casual labour, except for shearing, is employed. Contractors are engaged for wheat harvesting, hay baling and lime and fertilizer spreading.

A Romney flock of 1,350 ewes and 400 ewe hoggets have been wintered over the 1961-62 and 1962-63 seasons. Romney rams are exclusively used and all the replacement ewes bred and reared on the property. The wether lambs are all fattened and sold to the freezing works while the cull ewe lambs are sold as replacement stock. A herd of 25 Aberdeen Angus cows is carried but in-calf heifers are purchased, for replacements, as required. The calves are sold as weaners in April or May. Carrying capacity has been rising steadily and the owner considers that with heavier rates of topdressing there is considerable scope for further expansion which would be taken up with cattle.

A cash crop of 20 acres of wheat has been grown for the last four years. The wheat stubble green feed, 20 acres of swedes and about 40 acres of hay are considered necessary to winter the stock. Permanent pasture will retain its vigour for more than 10 years and the owner is reluctant to plough more than 40 acres annually. The following rotations have been used for the last four seasons:

	Acres
Old grass to wheat	20
Wheat stubble green feed	20
Stubble to permanent grass	20

and

Old grass to swedes	20
Swedes to permanent grass	20

All new grass is spring sown in November.

The owner said that sugar beet would replace wheat, as wheat was difficult to harvest in good condition and requires drying in many years.

7.5 SINGLE ENTERPRISE ANALYSIS OF CASE FARM 1

In this section the methods used are described in detail, together with the interpretation of the results. Since similar methods have been used for Case Farms 2 (Sections 7.7 and 7.8) and 3 (Section 7.10), the discussion in these three sections is confined to the presentation and interpretation of results.

Activities have been defined as single enterprises for Case Farm 1. No attempt has been made to define rotations in advance and the costs and resource requirements of regrassing have been regarded as overheads.

7.5.1 Activities

Activities may be production activities such as cash crops and livestock or they may be intermediate activities such as fodder crops and grazing. Intermediate activities do not enter directly into production but contribute indirectly, usually, through livestock activities. Buying, hiring and transfer activities can also be included. For Case Farm 1, four production and four intermediate activities have been considered. They are listed below.

Cash Crop Activities:		Units
P_1	Wheat	1 acre
P_2	Sugar Beet	1 acre

Intermediate Activities:		
P_3	Swedes	1 acre
P_4	Hay	1 acre
P_5	Arable Grazing	1 acre
P_6	Non-Arable Grazing	1 acre

Livestock Activities:		
P_7	Sheep	10 ewe equivalents
P_8	Cattle	1 breeding cow

Notes on the Activities

(a) The average yield of wheat is 55 bush. per acre and returns 13/6 per bush. gross.

(b) Sugar beet yields have been assessed at 15 tons of topped and washed beet and 7 tons of edible tops per acre. The yield of tops has been lowered because of the exposed nature of the property and the likelihood of severe wind damage.

(c) The average swede yield is 40 tons per acre.

(d) The yield of medium quality hay has been assessed at 1.5 tons per acre. Allowance has been made for the seasonal grazing obtainable from the hay paddocks.

(e) The two grazing activities represent the arable and non-arable grassed areas (including new grass) of the farm. The feed supplied is an estimated average (in terms of ewe equivalents) of the permanent grass of all ages. Lower pasture yields have been assessed for the non-arable grazing activity.

(f) The livestock activities are as described in Section 7.4.

7.5.2 Gross Margins

The gross revenue, variable costs and gross margins are given in Appendix II. By maximizing the revenue based on these gross margins, the returns to the fixed resources are maximized, subject to the constraints enumerated in Section 7.5.3.

Mathematically we are maximizing the function

$$Z = \sum_{j=1}^{n} c_j x_j$$

Subject to

$$\sum_{j=1}^{n} a_{ij} x_j \leqslant b_i \qquad ;i = 1, 2, \ldots, m$$

and $\qquad x_j \geqslant 0$

Where

Z = revenue

c_j = the gross margin of the j-th activity

x_j = the level of the j-th activity

a_{ij} = the per unit requirements of the j-th activity for the i-th resource

b_i = the level of the i-th constraint

n = the number of activities

and m = the number of constraints

Expressed in vector notation this becomes

$$Z = \underline{c}\underline{x}' \quad \text{a maximum}$$

Subject to

$$A\underline{x}' \leqslant \underline{b}'$$

$$\underline{x} \geqslant 0$$

Where $\underline{x}$ is a 1xn vector, with j-th element x_j,

$\underline{c}$ is a 1xn vector, with j-th element c_j,

$\underline{b}$ is a 1xm vector, with j-th element b_j,

and A is a matrix of requirement coefficients, with typical element a_{ij}.

7.5.3 Resource Supplies and Constraints

The resources available and the constraints imposed on the level of the activities are defined below.

(a) Labour

The derivation of meaningful labour coefficients has been one of the most difficult phases of the whole study. This is particularly so on sheep farms where it is very difficult to assign labour hours to specific activities, particularly livestock activities. The coefficients derived are subject to considerable variance and a large proportion of the available labour has to be considered as overhead labour. As mentioned in Section 6.2, the actual labour supply is variable and depends upon the circumstances at any particular time.

In view of these labour characteristics it was decided to set monthly labour supplies at what may be termed a "normal" maximum. That is, the maximum number of hours the permanent labour force would be prepared to work at peak periods, in "normal" circumstances. Because some people are prepared to work harder than others, this "normal" maximum was set at two levels. The lower level of 470 hours per month[8] assumes that the owner would be willing to work 60 hours per week and the employee 48.5 hours per week, while the higher level of 570 hours per week requires the owner to work 72 hours and the employee 60 hours per week. It is emphasised that these maximums will only be approached in peak periods and

(8) A month is taken as $\frac{52}{12} = 4\frac{1}{3}$ weeks.

actual hours of work in slack periods will be very much lower.

No allowances have been made for holidays or for time off work for other reasons. It is assumed that holidays will be taken in slack months and all the work that cannot be directly allocated to a single enterprise can be carried out in the months where labour is in disposal. Any other relevant assumptions concerning labour could be readily incorporated into the basic model.

(b) Land

The 250 acres of arable land is considered suitable for all crops and grazing. The non-arable area is assumed to be suitable only for grazing. No account has been taken of paddock size.

(c) Feed Reconciliation

The feed supplied by each intermediate activity and sugar beet and the requirements of the livestock activities are shown in Appendix III. The farming year has been divided into three, four monthly periods and all estimates of supplies and requirements are in terms of ewe equivalents.[9] This approach suffers from the disadvantages of techniques which use average figures but the data available would not justify a more sophisticated approach. The linear programming models seem, generally, to reflect fairly closely the present position on the Case Farms.

A hay reconciliation row is included to ensure that a minimum quantity is produced. Some hay is considered essential for the physiological well-being of the stock.

(d) Crop Restrictions

For reasons of fertility and crop health, acreage restrictions have been set on the various crops. Wheat has been limited to 80 acres, which

(9) See Farm Planning and Budgeting Manual - 1962, pp. 21-24, used by the Farm Management Department, Lincoln College.

is approximately one-third of the arable acreage, while sugar beet has been limited to 60 acres or one-quarter of the arable acreage. The maximum area of cash crops (wheat and sugar beet) has been limited to 125 acres.

These cropping restrictions have been imposed by the author and not by the farmer and with present knowledge are, perhaps, the upper limits of a cropping regime. One of the objectives of the study is to investigate the full range of cropping possibilities and more restrictive cropping limits could be readily incorporated. Other cropping enterprises such as oats, barley, and potatoes could have been considered but these could not be produced on a large scale in the district and remain profitable, because the capacity of existing outlets is limited. This does not apply to wheat or sugar beet.

The basic matrix is shown in Appendix III with disposal activities omitted.

7.5.4 Initial Solutions

Four farm plans have been derived from the basic matrix and are shown in Table 7.1. Three levels of top utilization have been considered because the tops are a valuable stock food but the possible extent of their use by sheep farmers is not known. Plans 2, 3 and 4 use zero per cent, 50 per cent and 100 per cent of tops respectively. Plan 1 is obtained when the sugar beet acreage is reduced to zero and wheat to 20 acres. This plan approximates the present policy on the farm.

Preliminary programming using a monthly labour availability of 470 hours indicated that only October labour limited farm plans. When monthly labour availability was set at 570 hours labour was in disposal(10) in every month for each plan as shown in Table 7.4. Therefore, labour has not been a limiting factor in the derivation of the four plans.

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(10) That is, some labour remained unused in every month.

TABLE 7.1

ACTIVITY LEVELS - CASE FARM 1

Activity	Units	Activity Levels			
		Plan 1	Plan 2	Plan 3	Plan 4
Wheat	1 Acre	20	65	65	65
Sugar Beet	1 Acre	0	60	60	60
Swedes	1 Acre	21	14	12	10
Hay	1 Acre	17	13	13	14
Arable Grazing	1 Acre	192	98	100	101
Non-Arable Grazing	1 Acre	250	250	250	250
Sheep	1 E.E.	1745	1265	1335	1404
Revenue	£	6549	8614	8878	9142

Notes:
1. All figures rounded.
2. September-December feed was in surplus in all plans.
3. Plans 2, 3 and 4 use zero, 50% and 100% of tops respectively.
4. Plan 1 approximates present policy.
5. Only one crop of wheat can be grown in the rotation.
6. See Table 7.5, section 7.5.5 for a further series of plans.

Table 7.1 shows the activity levels and revenue of the four plans. The sugar beet activity enters Plans 2, 3 and 4 at its maximum level with wheat taking up the remainder of the allowable cash cropping acreage. Plans 2, 3 and 4 differ only to the extent that additional swedes have to be grown to replace the sugar beet tops with a consequent fall in carrying capacity. When account is taken of the reduced capital investment in stock in Plan 2, the full utilization of the tops is worth £507 (£9142 - £8614 - £21[11]) compared with zero utilization. If the proportion of edible tops was raised above its assumed level of 52 per cent this figure would be higher.

The limits of the gross margins over which each solution is optimal are set out in Table 7.2. These limits are very wide. The calculated gross

(11) 139 less sheep : £347 @ 6% = £21.

margins tend to be centrally placed within the range which indicates that the plans are stable and large price or yield changes would be required to change an optimum farm plan. For example, Plan 4 remains optimum as long as the wheat gross margin remains in the range £16.1 to £52.4, all other factors remaining the same. The values for swedes show that the cost of growing swedes could rise to £50.7 or they could return up to £17.2 before the plans would change. If this cost or return was exceeded then a new optimum plan would be derived.

TABLE 7.2

GROSS MARGIN STABILITY LIMITS - CASE FARM 1

Activity	Plan	Lower Limit (£)	Upper Limit (£)
Wheat	1	16.1	∞
	2	16.1	43.6
	3	16.1	48.0
	4	16.1	52.4
Sugar Beet	1	25.2	∞
	2	20.8	∞
	3	16.4	∞
Swedes	All Plans	-50.7	17.2
Hay	All Plans	-345.0	5.3
Arable Grazing	All Plans	-16.4	9.3
Non-Arable Grazing	All Plans	-10.3	∞
Sheep	All Plans	19.7	58.1

<u>Note</u>: All figures rounded.

The imputed values (shadow prices) of the constraints and the activities not in the plan are shown in Table 7.3. These values indicate the penalty to the total system if a unit of the relevant variable is forced into the final solution. For example, the shadow price of the maximum cash crop constraint is £9.2. If this constraint was made more restrictive, say from 175 to 174 acres, then revenue would fall by £9.2 provided the plan was optimally adjusted after the change. (If the constraint was relaxed then revenue would increase.) The shadow prices are, of course, marginal values, but it should be noted that these may change numerically as a constraint is continuously relaxed or made more restrictive.

The shadow price for non-arable land indicates that a rent of up to £9.4 per acre could be paid for additional non-arable land. The shadow price of £16.1 for arable land applies only if this land is used for non-cash crops and grazing. If a proportion of this additional land could be used for cash cropping, the imputed value would be higher. For example, if half of the additional land could be used for cash cropping its rental value is increased to £16.1 + $£\frac{9.2}{2}$ = £20.7 per acre and if a quarter could be used for sugar beet its rental value (in Plan 4) is increased to £16.1 + $£\frac{27.2}{4}$ = £22.9 per acre. These values remain constant until some other factor becomes limiting.

TABLE 7.3

IMPUTED VALUES - CASE FARM 1

Activity not in Plan or Constraint	Units	Imputed Values (£)			
		Plan 1	Plan 2	Plan 3	Plan 4
Max. Cash Crop	1 acre	-	9.2	9.2	9.2
Max. Sugar Beet	1 acre	27.5	18.4	22.8	27.2
Arable Land	1 acre	16.1	16.1	16.1	16.1
Non-Arable Land	1 acre	9.4	9.4	9.4	9.4
Jan.-April Feed	1 E.E.	3.2	3.2	3.2	3.2
May-Aug. Feed	1 E.E.	0.5	0.5	0.5	0.5
Hay Reconciliation	1 Ton	7.6	7.6	7.6	7.6
Cattle	1 Cow	11.8	11.8	11.8	11.8

Note: All figures rounded.

TABLE 7.4

MONTHLY LABOUR IN DISPOSAL -
CASE FARM 1

Month	Plan 1 (hours)	Plan 2 (hours)	Plan 3 (hours)	Plan 4 (hours)
January	446	481	480	478
February	430	450	445	439
March	382	426	423	420
April	505	323	320	318
May	458	225	225	224
June	490	305	302	299
July	478	445	442	438
August	414	410	406	403
September	359	269	263	257
October	82	88	72	55
November	474	407	403	399
December	505	473	471	468
Totals:	5023	4302	4252	4198

Note: All figures rounded.

If a cattle activity were forced into the plan then income would fall by £11.8 per cow. Thus the 25 breeding cows being carried at present are reducing the potential revenue by £295. If, however, these cattle are necessary for the development and maintenance of good pasture on the steeper areas of the farm then a constraint could be included in the model to ensure that cattle are carried.

Although the exact areas of sugar beet, wheat and swedes indicated for Plan 4 may not be sown in practice, the following is one possible rotation which will be used to assess regrassing costs and labour requirements so that comparisons with Plan 1 can be made.

	Acres
Old grass to wheat	50
Wheat to sugar beet	50
Sugar beet to new grass	50

and

Old grass to swedes	10
Swedes to wheat	10
Wheat to sugar beet	10
Sugar beet to new grass	10

and

Old grass to wheat	5
Wheat to new grass (Spring sown)	5

This rotation requires 65 acres of new grass to be sown in November. Sufficient spring labour is available to enable this to be done.

A comparison of Plans 4 and 1 in Tables 7.1 and 7.4 shows that Plan 4 requires 825 additional hours of labour and returns £2,593 more than Plan 1. When adjustments are made to take account of the different fixed costs, regrassing costs and regrassing labour requirements (see section 7.2.1) the revenue advantage is reduced to £2,090 and the man hours required increased to 939, as follows:

	£	£
Extra Depreciation:		
Sugar Beet Machinery: £1500 @ 15%		225
Extra Interest on Capital:		
£1500 @ 6%	90	
341 less sheep: £850 @ 6%	51	39
Extra Regrassing:		
45 acres @ £5.3		239
		503

∴ Net advantage to Plan 4 = £2,593 less £503

= £2,090

Extra Labour:

45 acres new grass @ 2.53 hrs. per acre	=	114 hrs.
Total labour	=	825 plus 114
	=	939 hrs.

∴ The additional return per hour

$$= \pounds\frac{2090}{939}$$

$$= \pounds 2.23$$

Now there would be additional overhead labour because of the intensive cropping, but this increase would have to be 1151 hours (2090 less 939) before the return would fall to £1 per hour.(12)

These results indicate that increased cropping of both wheat and sugar beet would give a high return to extra labour. No account has been taken of any possible difficulty in harvesting wheat on this particular farm. This is because there are many farms of similar contour in the district, where this particular problem is less important.

7.5.5 Parametric Solution

In this section the model has been altered to exclude all but the October labour constraint which has been set at 468 hours. This demands a 60 hour week from the owner and a 48 hour week from the employee. (It will be recalled that only October labour was limitational when the monthly labour supply was set at 470 hours.) An October labour supplying activity has been added with a gross margin of minus 10/- per hour. This activity may be interpreted in two ways. Firstly, the permanent labour force may be prepared to work additional hours as long as the marginal return does not fall below 10/- per hour. Any

(12) It is assumed that sugar beet plant and machinery is purchased when the farm plan includes a sugar beet enterprise. Therefore, the overhead labour requirements on machinery repairs and maintenance will be higher in Plan 4 than in Plan 1.

October labour supplied by this activity meets this requirement. Secondly the activity can be regarded as the supply of casual labour at 10/- per hour.

A meadow hay buying activity has been added to allow the purchase of meadow hay at £7.5 per ton, landed on the farm.

Except for these modifications the model is the same as before. Top utilization has been set at 100 per cent. Plan 10 was derived using the original gross margins for sugar beet and wheat. Plan 9 was then computed by setting the sugar beet gross margin just below the lower limit at which Plan 10 was optimal. This process was continued until sugar beet left the plan and then with sugar beet gross margin at zero the wheat gross margin was reduced until wheat also left the plan. The results are tabulated in Table 7.5.

TABLE 7.5

RESULTS OF THE PARAMETRIC SOLUTION - CASE FARM 1

Activity	Units	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
Sugar Beet	acres	0	0	0	32.5	45	60
Wheat	acres	0	45	80	80	80	65
Swedes	acres	23	20	18	13.5	12	11
Arable Grazing	acres	227	185	152	124	113	114
Non-Arable Grazing	acres	250	250	250	250	250	250
Hay Buy	tons	28	25	23	22	21	22
Oct. Labour Supply	hours	59	0	0	0	17	58
Sheep	E.E's	1886	1674	1510	1434	1406	1441
Revenue	£	6406	6430	7157	7178	7609	9167
Sugar Beet G.M.	£	0	0	7.2	8.0	17.6	43.59
Wheat G.M.	£	15.4	16.1	25.24	25.24	25.24	25.24

Note: All figures rounded.

The important revenue comparisons in Table 7.5 are:-

	Revenue (£)
Plan 5 (Cash crops nil)	6,406
Plan 7 (Maximum wheat)	7,157
Plan 10 (Optimum combination)	9,167

When these values are adjusted for the different overhead costs of regrassing, stock and machinery (compared with Plan 1) we have:

	Revenue (£)
Plan 5	6,265
Plan 7	6,768
Plan 10	8,553

These figures show that revenue increases by £503 when 80 acres of wheat are grown (sugar beet excluded) and increases by £2,288 when 60 acres of sugar beet and 65 acres of wheat are grown. Plan 10 has a revenue of £1,785 greater than Plan 7, which shows that sugar beet is a very profitable crop. If the wheat yields were higher, as they are on many farms, wheat growing would be relatively more profitable and reduce the relative advantage shown by sugar beet (see Fig. 7.2). Further, if the cash cropping constraints were more restrictive on this farm it would pay to reduce the wheat acreage and grow the maximum amount of sugar beet. This may create some cultural problems because wheat is a good crop to precede sugar beet.

Wheat would also be relatively more profitable if two successive crops could be grown, thus reducing the overhead costs of regrassing. This would be possible on some farms but is considered unwise on farms of similar topography because of the effect on soil structure and fertility.

The gross margin stability limits for wheat and sugar beet are shown in Table 7.6.

TABLE 7.6

GROSS MARGIN STABILITY LIMITS FOR WHEAT AND SUGAR BEET

	Sugar Beet Gross Margin (£)		Wheat Gross Margin (£)	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Plan 5	-	-	-	15.5771
Plan 6	-	-	15.5772	16.2351
Plan 7	-	7.3454	16.2352	∞
Plan 8	7.3455	8.0476	15.6219	∞
Plan 9	8.0477	17.7105	25.1295	∞
Plan 10	17.7106	∞	15.5772	51.1194

Figure 7.1 shows how the plans change as sugar beet gross margin is raised from zero. Since linear programming is being used the plans change discretely and revenue increases at an increasing rate as plans change. Plans 7 and 9 are optimum over relatively wide gross margin ranges while Plan 8 is optimum over an extremely narrow range and is therefore unstable. Owing to the constraints applied to the model, the plan does not change when the gross margin of sugar beet exceeds £17.7105 per acre (and wheat gross margin is less than £51.1194 per acre). This indicates clearly the profitability of the crop even when labour in excess of 468 hours in October is being paid 10/- per hour.

Figure 7.2 shows how plans change as the wheat gross margin is increased from zero with sugar beet excluded from the plan. The supply functions for sugar beet and wheat are redrawn in Figures 7.3 and 7.4 with the standard arrangement of axes. It is interesting to note that this analysis indicates that the introduction of sugar beet would tend to increase, rather than decrease, the present wheat acreage.

The limits of the meadow hay buying activity and the shadow prices of growing hay are shown in Table 7.7.

Fig. 7·1 Parametric Solution - Case Farm 1

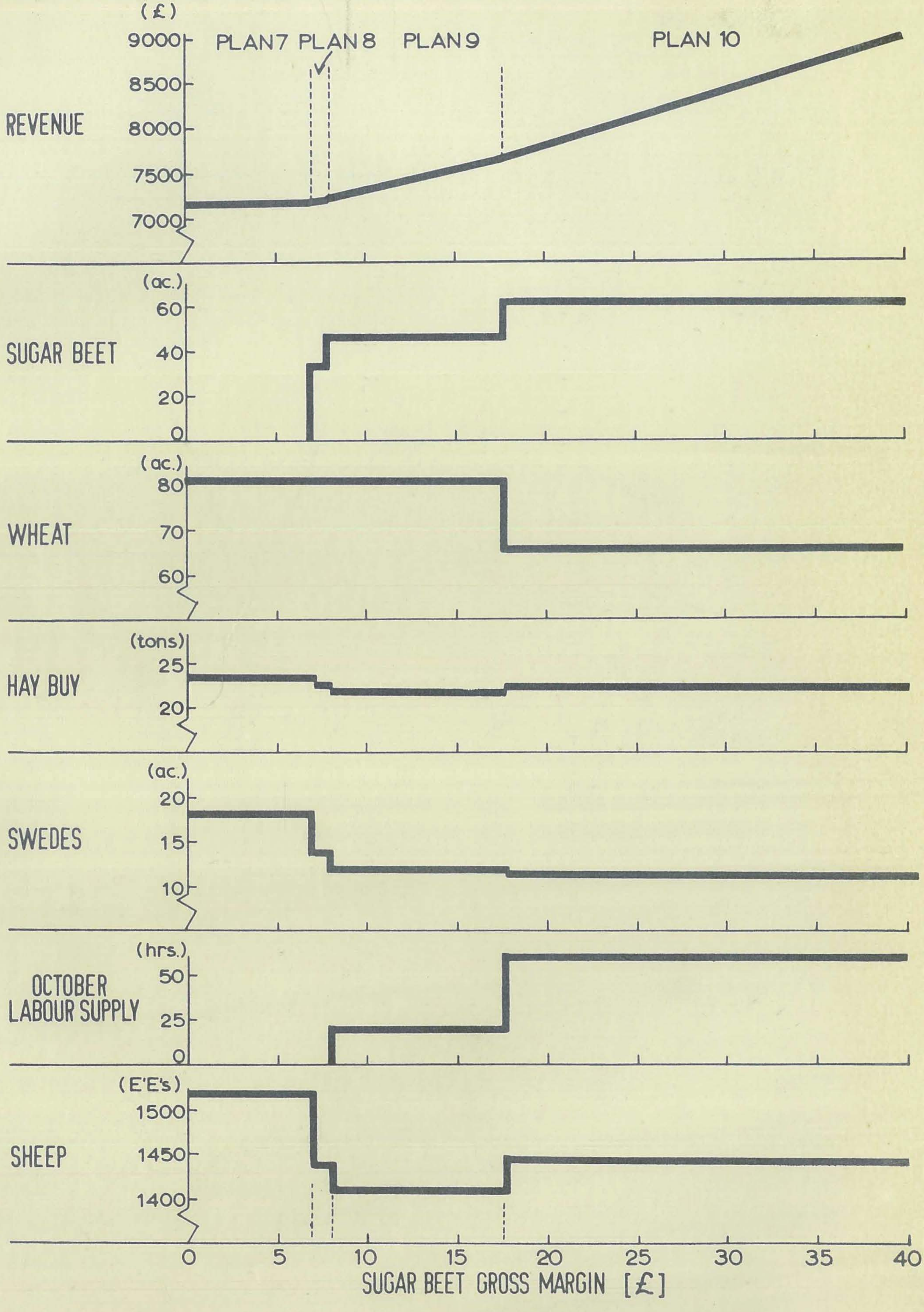

Fig. 7·2 Parametric Solution - Case Farm 1

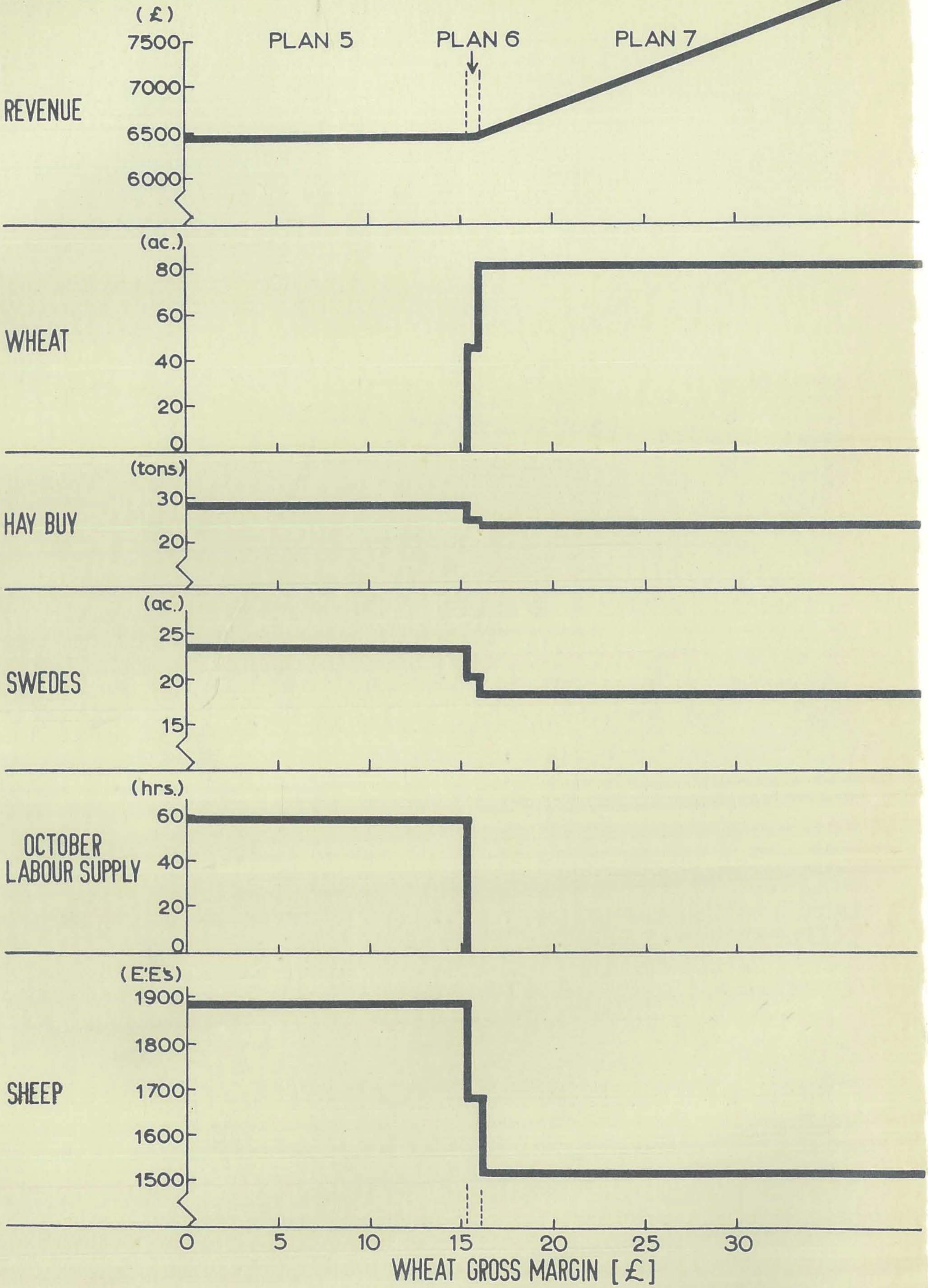

Fig. 7·3 Sugar Beet Supply Function

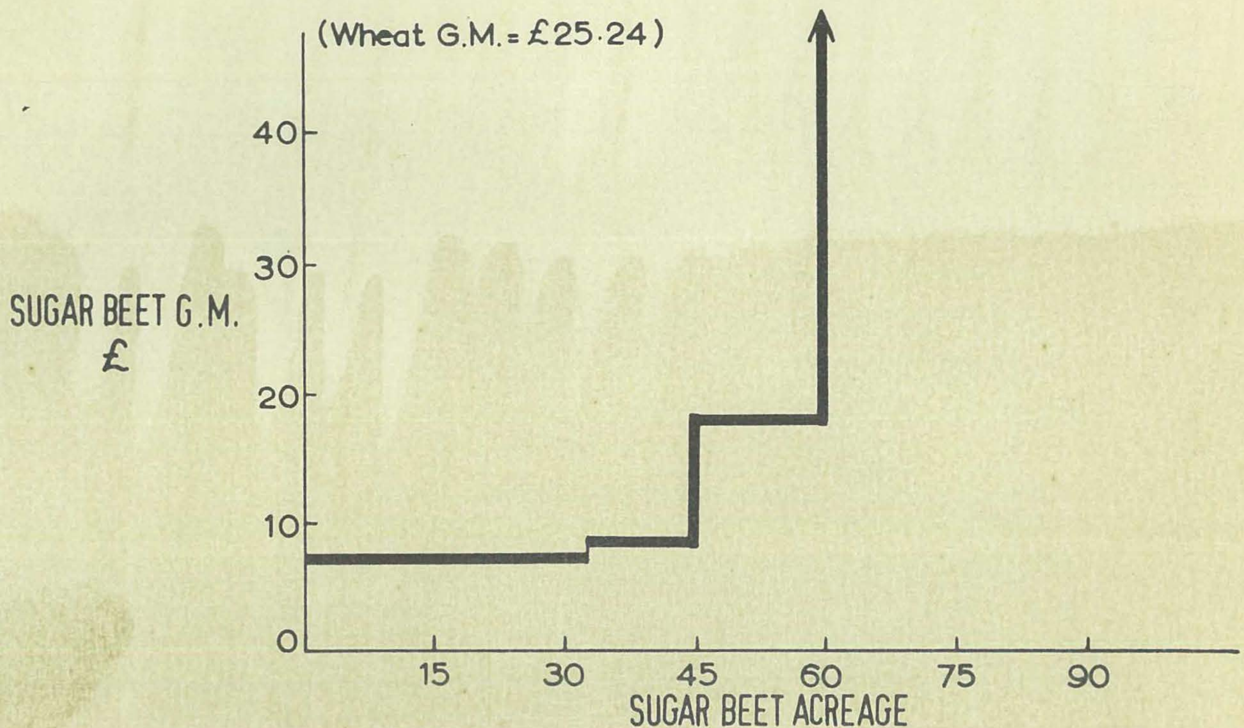

Fig. 7·4 Wheat Supply Function

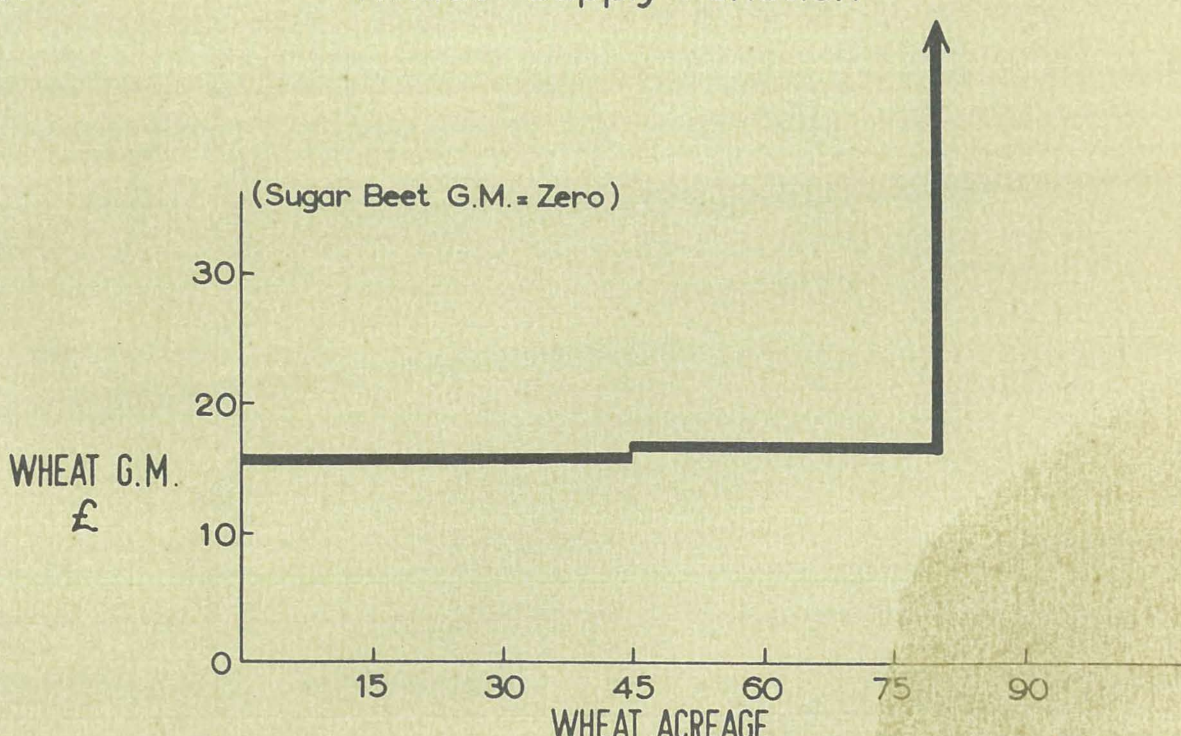

TABLE 7.7

GROSS MARGIN LIMITS OF BUYING HAY AND SHADOW PRICES OF GROWING HAY

	Buying Hay (per ton)		Growing Hay (per acre) Shadow Price (£)
	Lower Limit (£)	Upper Limit (£)	
	(1)	(2)	(3)
Plan 5	- 9.77	- 2.42	3.49
Plan 6	- 9.42	- 2.43	3.80
Plan 7	-10.02	- 2.45	3.88
Plan 8	- 8.87	- 2.43	3.52
Plan 9	- 9.77	- 4.39	3.49
Plan 10	- 9.77	- 2.42	3.49

Columns (1) and (2) of Table 7.7 show that it pays to buy hay if the cost lies in the range £10.02 to £2.42 per ton. If the cost exceeds the values in column (1) then hay should be made on the farm. Column (3) shows the penalty per acre of hay, if it is produced. The effect of growing hay on the plans in this section would be to slightly lower carrying capacity as less grazing would be available.

7.5.6 Summary

The important results from section 7.5 are presented in Table 7.8. The results show that the growing of the maximum area of cash crop (wheat and sugar beet) could increase revenue substantially on farms that are similar to the one described. Plans 2, 4 and 10 are stable since large price and yield variations would be required to reduce the gross margins to their lower stability limits.

The feeding value of the tops is clearly shown. On farms where higher crop yields are obtainable the tops may show a higher return and the relative profitability of wheat may be increased.

TABLE 7.8

SUMMARISED RESULTS - CASE FARM 1

Plan	Wheat (acres)	Sugar Beet (acres)	Tops Used	Revenue (£)
Results from 7.5.4:				
1	20	0	-	6,443
2	65	60	zero	8,026
4	65	60	100%	8,533
Results from 7.5.5:				
5	0	0	-	6,265
7	80	0	-	6,768
10	65	60	100%	8,553

Notes: 1. The revenues shown have been adjusted for the different overhead costs of each plan, i.e., the fixed costs still to be met are approximately the same in each plan.

2. The results from the two sections are not exactly comparable. In section 7.5.5 October labour in excess of 468 hours is being paid 10/- per hour and hay is purchased, while in section 7.5.4 labour is not limitational and hay is made on the farm. It can be seen, however, from Plans 4 and 10 that these differences have only a minor effect on revenue.

It is emphasized that an extra 939 hours of direct labour is required to obtain this increased revenue. Some additional overhead labour will also be needed. Whether this additional labour will be forthcoming is a question which should be very carefully examined. (See Chapter 8.)

7.6 PRESENT MANAGEMENT POLICY ON CASE FARM 2

The farm is situated on the Milton Plain, 20 miles by road from Balclutha and one mile from the nearest railway station. The whole area of 367 acres is flat but a tree lined stream meanders through the property, which, together with buildings, reduces the cultivable area to 350 acres. The soil is Tokomairiro silt loam which is liable to pug severely in wet winters.

Capital problems are unlikely since there is only a small mortgage and a substantial cash reserve is available. Farm taxable profit has been in the £3,000 to £4,500 range over the three years 1958-59 to 1961-62. A full range of plant and machinery is available.

The owner and one single man constitute the permanent labour force, casual labour being employed for shearing only. Contractors are engaged for cereal harvesting and hay baling.

A fat lamb producing flock of 1,500 Romney ewes is carried. All ewes are mated to Southdown rams and all lambs sold fat, replacement two-tooth ewes being purchased each February. Approximately thirty yearling steers are purchased in the autumn, carried through the winter, fattened and sold the following April. The number of cattle varies and is dependent on seasonal feed supplies. Carrying capacity has been rising steadily over the last few years and has now reached, in the owner's view, the maximum for breeding ewes. Any further capacity will be taken up with dry sheep and cattle. There is interest in the possibility of housing cattle during the winter to avoid pasture wastage and damage due to pugging.

Cash crops of barley and wheat are grown. The acreage of wheat is being increased annually so that a stable rotation has not yet been evolved. Fifteen acres of swedes, fifteen acres of green feed barley and twenty-five acres of hay are considered necessary to winter the stock. Thirty acres of old grass are ploughed each year and there is reluctance to plough more because pasture renewal is not necessary for up to fifteen years. The following rotations, which may involve a reduction in stock carrying capacity, are under consideration.

	Acres
Old grass to wheat	15
Wheat to swedes	15
Swedes to wheat	15
Wheat to green feed barley	15
Green feed to grain barley (resown)	15
Barley to permanent grass	15

and

Old grass to wheat	15
Wheat to permanent grass	15

An alternative to the latter rotation could be:

Old grass to wheat	15
Wheat to 2-year temporary pasture	15
Temporary pasture to wheat	15
Wheat to permanent grass	15

The owner thought that he could grow a small acreage of sugar beet after wheat sown from old grass.

Since this farm is in most respects suitable for intensive sugar beet cultivation and is broadly similar to many highly developed fat lamb producing farms in districts with similar climatic conditions (particularly Southland) the results may have a wide application.

7.7 SINGLE ENTERPRISE ANALYSIS OF CASE FARM 2

The activities, resource supplies and constraints are described in this section and the linear programming results briefly summarised. The costs and resource requirements of regrassing have been regarded as overheads. In section 7.8 a model using rotational activities is formulated and the results discussed in detail.

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7.7.1 Activities

The seven production and three intermediate activities included are listed below.

Cash Crop Activities		Units
P_1	Wheat	1 acre
P_2	Barley (Grain)	1 acre
P_3	Greenfeed Barley followed by Grain Barley	1 acre
P_4	Sugar Beet	1 acre
Intermediate Activities		
P_5	Swedes	1 acre
P_6	Hay	1 acre
P_7	Grazing	1 acre
Livestock Activities		
P_8	Sheep	10 ewe equivalents
P_9	Wethers	10 wethers
P_{10}	Cattle	1 rising 2 year steer

Notes on the Activities

(a) The average yield of wheat is 60 bush. per acre for both a first and second crop. A portion of the crop can be stored thus gaining a storage increment making the average price 14/- per bushell.

(b) The average yield of barley is 45 bush. per acre and the contract price 15/- per bushell. The straw is baled and sold at 3/- per bale.

(c) Greenfeed barley follows wheat and is followed by a sowing of barley for grain.

(d) Sugar beet yields are 17.5 tons of topped and washed beet and 9.5 tons of edible tops per acre. Three levels of top utilization are considered - 9.5 tons, 4.75 tons and zero tons per acre.

(e) The swede crop yields 45 tons per acre.

(f) The yield of medium quality hay has been assessed at 1.5 tons per acre. Allowance has been made for the seasonal grazing obtainable from the hay paddocks.

(g) The grazing activity represents the grassed area of the farm and feed supplied is an estimated average of the permanent grass of all ages.

(h) The sheep enterprise consists of a fat lamb producing flock as described in section 7.6.

(i) The wether activity cannot be defined precisely because of the nature of the enterprise. It is assumed that two-tooth wethers are purchased in January-February, wintered, shorn and sold in slaughter condition during the following spring and summer.

(j) The cattle activity involves the purchase of yearling steers in the autumn, wintering and fattening them for sale in the following April or May to the freezing works.

7.7.2 Gross Margins

The gross revenue, variable costs and gross margins are detailed in Appendix II.

7.7.3 Resource Supplies and Constraints

The resources available and the constraints imposed on the level of the activities are defined below.

(a) Labour

Monthly labour supplies were determined in exactly the same way as in section 7.5.3.

(b) Land

The farm is flat and consists of a uniform soil type and, after the deduction of unploughable land, the remainder (350 acres) is considered to be suitable for all crops and grazing. No account has been taken of paddock size.

(c) Feed Reconciliation

The feed supplied by each intermediate activity and sugar beet and the requirements of the livestock activities are shown in Appendix III.

(d) Crop Restrictions

The maximum production of cereals, barley and sugar beet have been set at 120, 25 and 85 acres respectively. Barley is set at a low level because of the difficulty of obtaining larger contracts. Cash crops are limited to 175 acres or half the total cultivable area.

The initial matrix is shown in Appendix III with disposal activities omitted.

7.7.4 Solutions

The computations have been carried out in exactly the same way as for Case Farm 1 except that a parametric gross margin solution is not included here but is presented in section 7.8.

The results are given in Table 7.9 and follow a similar pattern to those of Case Farm 1 with sugar beet entering the plans at its maximum level of 85 acres and wheat taking up the remaining 90 acres of the permissible cash crop acreage. The full utilization of the sugar beet tops completely eliminates the need for a swede crop. Barley, wethers and cattle do not enter the plans.

TABLE 7.9

ACTIVITY LEVELS - CASE FARM 2

Activity	Units	Activity Levels			
		Plan 1	Plan 2	Plan 3	Plan 4
Wheat	1 Acre	70	90	90	90
Sugar Beet	1 Acre	0	85	85	85
Swedes	1 Acre	12	7	3	0
Hay	1 Acre	13	8	9	11
Grazing	1 Acre	255	160	163	164
Sheep	1 E.E.	1,302	814	938	1,056
Revenue	£	6,168	9,447	9,874	10,280

Notes: 1. All figures rounded.

2. Plans 2, 3 and 4 utilize zero per cent, 50 per cent and 100 per cent of tops respectively. Except for the substitution of an additional 15 acres of wheat for 15 acres of barley, Plan 1 approximates present policy. The shadow price of barley is £2.9 and if 15 acres were forced into Plan 1, revenue would be reduced by £44.

3. Carrying capacity in Plan 4 reaches a maximum of 6.4 ewe equivalents per grazing acre.

4. September-December feed is surplus in all Plans.

5. Two successive crops of wheat can be grown.

The additional revenue obtained from intensive cash cropping is £4,112 which, when adjusted as in section 7.5.4, is reduced to £3,519. This is an extra return of £2.35 per hour. The net value of the tops is £797. These results again illustrate the high returns that could be obtained from wheat and sugar beet grown intensively.

7.8 ROTATIONAL ENTERPRISE ANALYSIS OF CASE FARM 2

So that regrassing resource requirements and costs could be included in the basic matrix instead of being treated as overheads a series of rotational activities have been derived. The construction of the model and the resultant new solutions are discussed below.

7.8.1 Activities

Since barley grain production did not enter previous plans it has not been considered in this section.

The cropping possibilities have been defined as follows:

(a) Grass can follow all crops.

(b) First year wheat can follow grass, sugar beet or swedes.

(c) Second year wheat can follow first year wheat, sugar beet or greenfeed barley.

(d) Sugar beet can follow grass, first year wheat or swedes.

(e) Swedes can follow grass, first year wheat, sugar beet and greenfeed barley.

(f) Greenfeed barley can follow first year wheat.

After the elimination of those rotations which were essentially the same - those that supplied the same quantity of feed and products but in a different order - 20 rotations remained for inclusion in the model. These rotations are listed in Appendix II. This reduction, together with the elimination of barley was an arbitrary decision but was necessary to keep the model to a reasonable size.

Wheat and sugar beet selling activities were included so that parametric gross margin changes could be made. Hay, grazing and livestock activities were retained in their original form.

7.8.2 Gross Margins

Gross margins for each rotation were calculated including the cost of regrassing but excluding the gross margins for sugar beet and wheat. The sugar beet and wheat selling activities were credited with their respective gross margins.

7.8.3 Resource Supplies and Constraints

The labour, land and feed reconciliation constraints were not changed. Sugar beet and wheat reconciliation constraints were included to transfer the sugar beet and wheat produced to their respective selling activities. A maximum wheat constraint was added and the maximum cereal and barley constraints deleted.

7.8.4 Initial Solutions

An optimum plan similar to Plan 4 in section 7.7.4 was derived. It again included 85 acres of sugar beet and 90 acres of wheat. Labour was in disposal in every month when its supply was set at 570 hours, but September labour became limiting when the monthly supply was reduced to 470 hours.

These results are not discussed further and we pass on immediately to the parametric solutions in the next section.

7.8.5 Parametric Solutions

The computations were carried out in exactly the same way as for Case Farm 1 in section 7.5.5. From section 7.8.4 it was clear that only September labour availability would limit farm plans. Therefore, September labour was set at 468 hours and a labour supplying activity, which supplied labour at 10/- per hour, included. This activity has the same interpretation as before. The other 11 labour constraints were eliminated. A meadow hay buying activity at £7.5 per ton was also included. Except for these additions and deletions the model remained the same as in section 7.8.4.

The results are tabulated in Table 7.10. Hay is purchased in all plans but its gross margin lower limit lies within the range £8.5 to £10 per ton. Therefore, the landed cost of hay has only to exceed this range for hay buying to become unprofitable. If hay was produced on the farm, carrying capacity would fall slightly.

TABLE 7.10

RESULTS OF PARAMETRIC GROSS MARGIN PROGRAMMING - CASE FARM 2

Activity	Units	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10	Plan 11	Plan 12	Plan 13	Plan 14	Plan 15
Sugar Beet Sell	1 acre	0	0	0	0	4	5	39	52	55	58	85
Wheat Sell	1 acre	0	14.5	25	120	120	120	120	120	120	117	90
Grazing	1 acre	334	321	312.5	225	222	220	189	178	175	175	175
Swedes	1 acre	16	14.5	12.5	5	4	5	2	0	0	0	0
Greenfeed	1 acre	0	0	12.5	5	4	0	0	0	0	0	0
Hay Buy	1 ton	25	24	23	17	17	17	16	15	15	15	16
Sheep	1 E.E.	1671	1605	1562	1126	1118	1114	1045	1021	1013	1020	1088
Sept. Labour Supply	1 hour	68	77	73	52	46	46	0	16	20	24	83
Rotation 20								1				
Rotation 19	4 acres					4						
Rotation 14	3 acres							38	52	55	58	45
Rotation 12	3 acres			12.5	5							
Rotation 8	2 acres		14.5									
Rotation 6	2 acres				55	56	55	20	8	5		
Rotation 3	1 acre											40
Rotation 2	1 acre	16					5					
Revenue	£	4873	4876	4955	6792	6794	6795	6817	6909	7651	8233	9743
Sugar Beet G.M.	£	0	0	0	0	4.4	4.7	5.4	7.2	20.7	30.7	48.51
Wheat G.M.		12.7	13.1	16.3	31.75	31.75	31.75	31.75	31.75	31.75	31.75	31.75

Note: 1. All figures rounded.

2. Greenfeed is occupying land for only five months and should not be included when checking on the total farm area.

Figure 7.5 shows how the farm plan changes as the sugar beet gross margin is raised from zero to £48.51 with the wheat gross margin constant at £31.75. It can be seen that at gross margins less than £7.3663 (see Table 7.11) plans are extremely unstable. Plans 8, 9, 10, 11 and 12 are optimum over extremely narrow gross margin ranges. Plans 13 and 14 are optimum over a wider range of values, and the farm plan becomes stable for all sugar beet gross margins above £30.8462 (and wheat gross margin less than £49.4137 per acre) when the maximum permitted acreages of wheat and sugar beet are grown. The profitability of intensive cropping is evident from the revenue function.

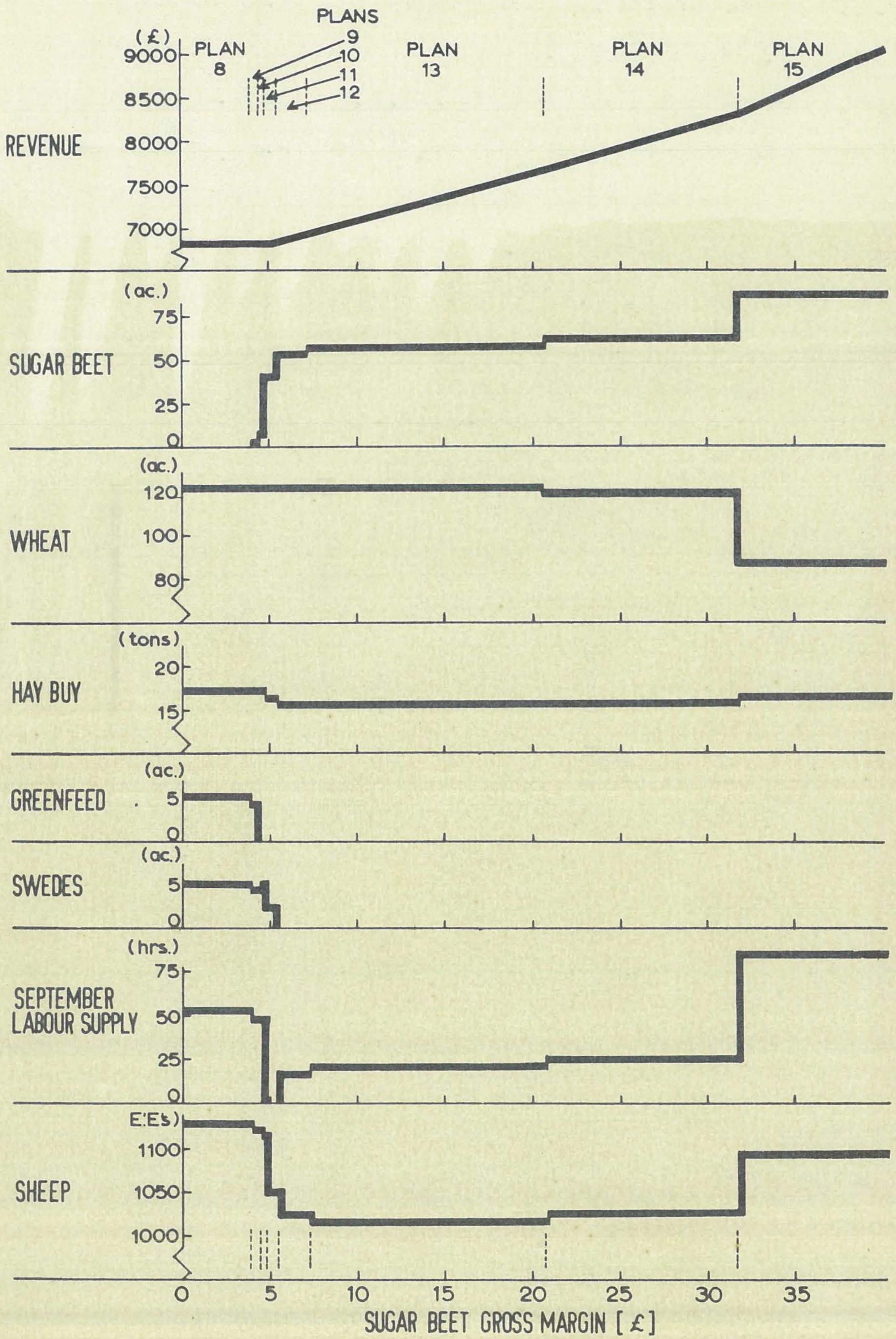
TABLE 7.11

SUGAR BEET AND WHEAT GROSS MARGIN LIMITS
CASE FARM 2 (£)

Plan	Wheat		Sugar Beet	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
5	-	12.8662	-	-
6	12.8663	13.2104	-	-
7	13.2105	16.4779	-	-
8	16.4780	∞	-	3.9626
9	16.5091	∞	3.9627	4.5887
10	16.5314	∞	4.5888	4.8615
11	16.6381	∞	4.8616	5.5257
12	18.0950	∞	5.5258	7.3662
13	31.5713	∞	7.3663	20.8787
14	31.6038	41.5712	20.8788	30.8462
15	14.9150	49.4137	30.8463	∞

It is also of interest to note that sugar beet tops provide all of the supplementary fodder crop requirements when 52 acres of sugar beet are grown. As sugar beet acreage increases to its maximum, the additional tops which become available enable carrying capacity to rise because they provide extra autumn and

Fig. 7·5 Parametric Solution - Case Farm 2



winter feed. This in turn creates the additional demand for September labour.

Figure 7.6 shows how the farm plan changes as the wheat gross margin is raised from zero to £31.75 with sugar beet gross margin at zero.

Figure 7.7 shows the normative supply function for sugar beet (wheat gross margin £31.75) with the standard arrangement of axes. The supply function for wheat (sugar beet gross margin zero) is given in Figure 7.8.

It is clear from these results that intensive cropping with wheat and sugar beet is very profitable. The important revenue comparisons in Table 7.10 are:

	Revenue (£)
Plan 5 (cash crops nil)	4,873
Plan 8 (maximum wheat)	6,792
Plan 15 (optimum combination)	9,743

When these values are adjusted for the different overhead costs of stock and sugar beet machinery (compared with Plan 1), we have:

	Revenue (£)
Plan 5	4,818
Plan 8	6,818
Plan 15	9,460

These figures show that revenue increases by £2,000 when 120 acres of wheat are grown (sugar beet excluded), and increases by £4,642 when 90 acres of wheat and 85 acres of sugar beet are grown. The addition of sugar beet to the wheat-sheep plan adds £2,642 to the farm revenue. Thus the inclusion of regrassing resource requirements and costs in the linear programming model makes little difference to the optimum farm plan. A comparison with Table 7.9 shows an increase in the grazing acreage and carrying capacity because hay has been purchased instead of being produced.

7.8.6 Summary

The important results from sections 7.7 and 7.8 are presented in Table 7.12.

Fig. 7·6 Parametric Solution - Case Farm 2

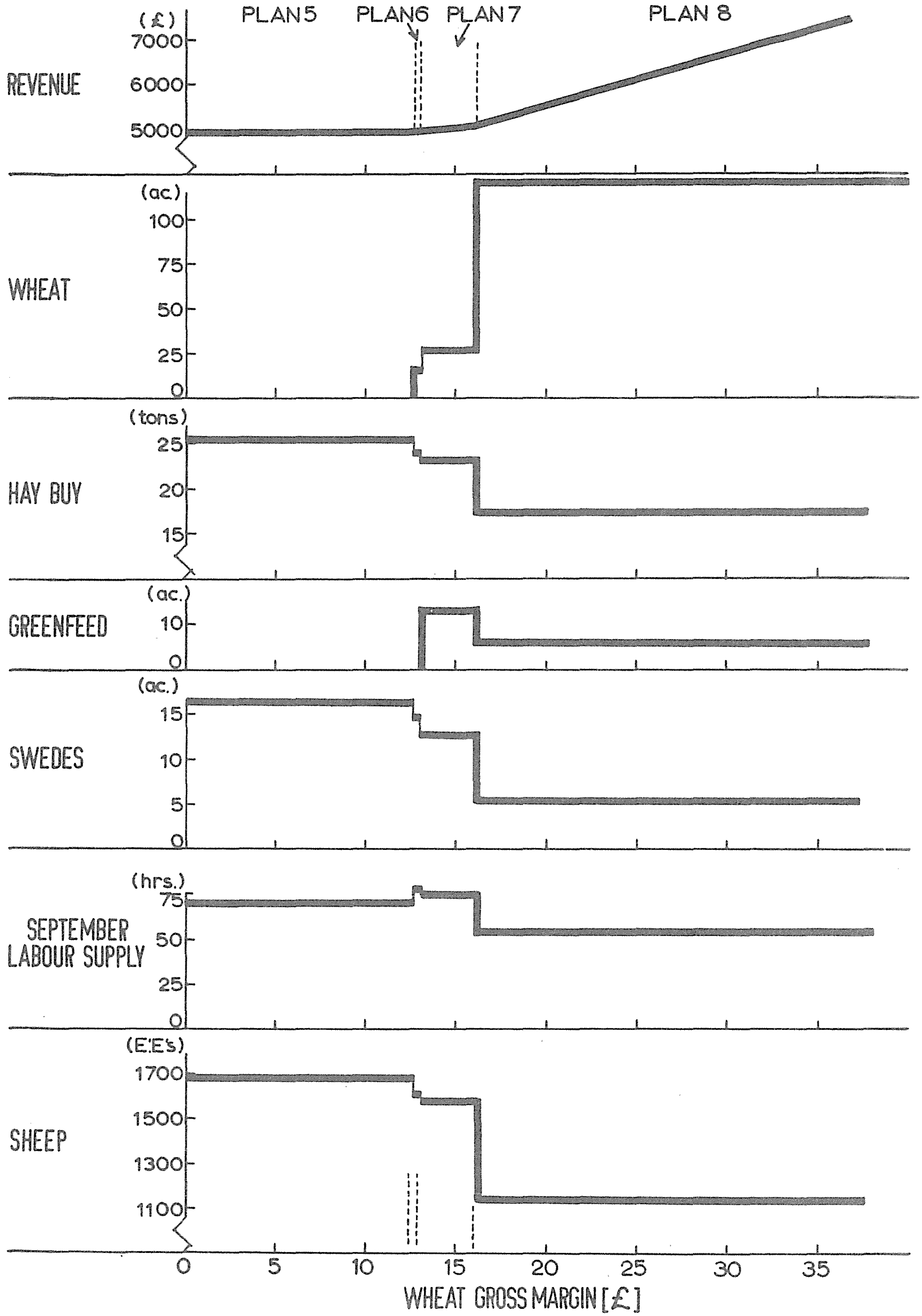


Fig. 7·7 Sugar Beet Supply Function

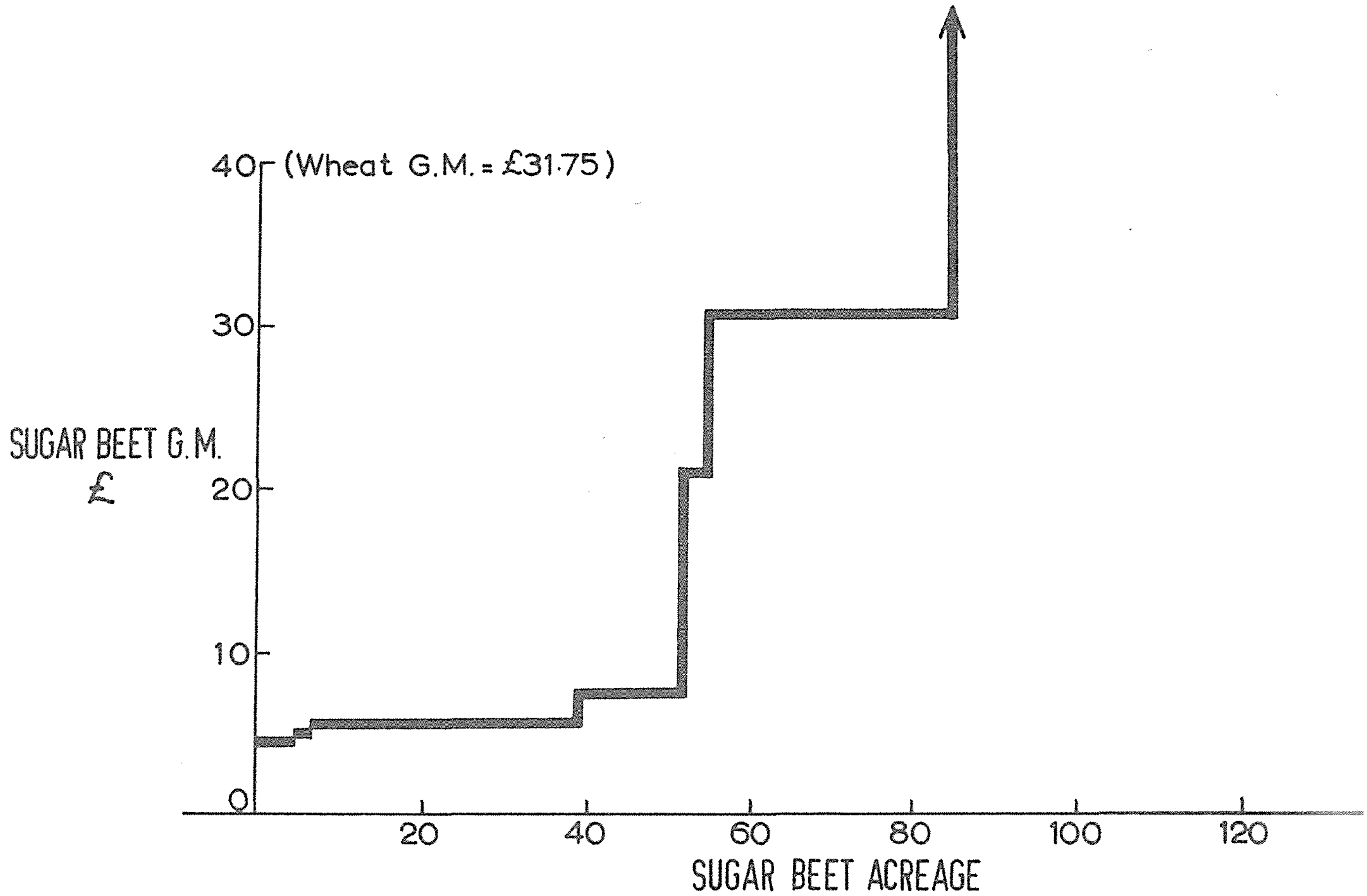


Fig. 7·8 Wheat Supply Function

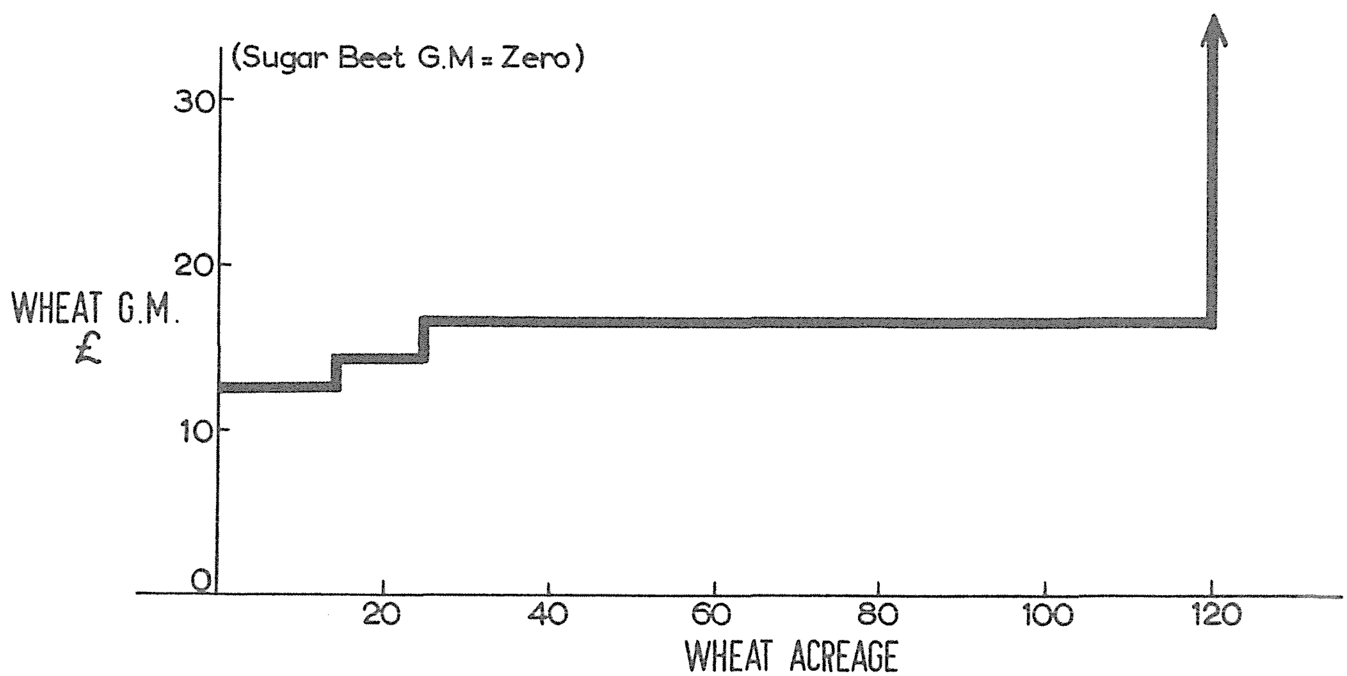


TABLE 7.12

SUMMARISED RESULTS - CASE FARM 2

Plan	Wheat (acres)	Sugar Beet (acres)	Tops Used	Revenue (£)
Results from 7.7.4:				
1	70	0	-	5,947
2	90	85	Zero	8,669
4	90	85	100%	9,466
Results from 7.8.5:				
5	0	0	-	4,818
8	120	0	-	6,818
15	90	85	100%	9,460

Notes: 1. The revenues have been adjusted for the different overhead costs of each plan.

2. The results of the two sections are not exactly comparable. In section 7.8.5 September labour in excess of 468 hours is being paid 10/- per hour and hay is purchased, while in section 7.7.4 labour is not limitational and hay is made on the farm. It is again seen from Plans 4 and 15 that these differences have only a minor effect on revenue.

The results of sections 7.7 and 7.8 show that intensive cash cropping with wheat and sugar beet could raise income substantially on this farm. Plan 15 is stable since large price or yield variations would be necessary to reduce the gross margins to their lower stability limits.

It should be emphasized that this result (as in Case Farm 1) depends upon the greater use of the available labour. In Plan 15 the direct annual labour requirements are increased by approximately 1,500 hours above those required under the present policy.

7.9 PRESENT MANAGEMENT POLICY ON CASE FARM 3

This dairy farm is situated in the Stirling district, 3 miles by road from Balclutha. The homestead block of 132 acres is flat, while the adjacent hill block of 30 acres is moderately to steeply rolling. This area of rolling land is not cropped but is used for grazing replacement and dry stock. The soil type at the home farm is the Clutha silt and sandy loam which is a deep, high fertility soil and suitable for intensive cropping. The hill block is Clydevale silt loam overlying a clay subsoil.

The home farm is subject to flooding by the Clutha River. Since 1940 there have been four floods, those in 1945 and 1957 being particularly severe. The owner estimated that regrassing, fencing repairs and loss of production cost him more than £2,000 in 1957. The river protection works now under construction should remove the danger of flooding, when completed. (The hill block was purchased two years ago to provide some land above the flood levels.)

There is a mortgage on the property but it is soundly arranged and there should be no difficulty in purchasing sugar beet machinery. Taxable farm profits have been in the £2,000 to £3,500 in recent years.

The permanent labour force consists of the owner, a single man and the part-time employment of an older man who works an average of 30 hours per week. School boys are employed for swede and mangold thinning and weeding. Since sugar beet sowing, thinning and weeding machinery is capable of treating swedes and mangolds in a similar way to sugar beet, its use has been assumed in the following exercise. Contractors are employed for hay baling, lime sowing and crop spraying.

A herd of 60 Jersey cows, 28 two year old heifers and 30 yearling heifers have been wintered in the 1961-62 and 1962-63 seasons. The Artificial Breeding Service is used and all replacements reared on the property.

Whole milk is produced and delivered to a near-by cheese factory for about nine months of the season. During the three winter months a 12 gallon town milk quota is supplied to the factory which acts as a receiving depot for the Dunedin milk supplying authority. Thus 5 or 6 cows must be milked through the winter.

A cash crop of 4 acres of main crop potatoes have been grown for many years. Fodder crops of swedes, mangolds, choumoellier and greenfeed barley are grown to provide autumn, winter and spring feed for the cattle. The following rotations have been used in recent years.

	Acres
Old grass to swedes	4
Swedes to potatoes	4
Potatoes to greenfeed barley	4
Greenfeed barley to permanent grass	4

and

Old grass to swedes	4
Swedes to mangolds	4
Mangolds to choumoellier	4
Choumoellier to permanent grass	4

All new grass is spring sown in November.

A five acre paddock of lucerne is grown from which four cuts of lucerne hay are taken each year, yielding a total of 750 bales. No silage or meadow hay is made on this farm.

The owner believed that sugar beet would substitute for a proportion of his present fodder crops and would grow that acreage but he was not prepared to contemplate a reduction in herd numbers.

7.10 SINGLE ENTERPRISE ANALYSIS OF CASE FARM 3

The activities have been defined as single enterprises and the regrassing costs and resource requirements regarded as overheads.

7.10.1 Activities

The six production and nine intermediate activities are listed below.

Cash Crop Activities:		Units
P_1	Potatoes	1 acre
P_2	Potatoes and greenfeed	1 acre
P_3	Wheat	1 acre
P_4	Sugar Beet	1 acre
Intermediate Activities:		
P_5	Winter choumoellier	1 acre
P_6	Autumn choumoellier	1 acre
P_7	Mangolds (for spring feed)	1 acre
P_8	Swedes (for winter feed)	1 acre
P_9	Arable grazing	1 acre
P_{10}	Non-arable grazing	1 acre
P_{11}	Winter lucerne hay	1 acre
P_{12}	Summer lucerne hay	1 acre
P_{13}	Autumn lucerne hay	1 acre
Livestock Activities:		
P_{14}	Dairy cows	10 E.E's.
P_{15}	Wethers	10 wethers

Notes on the Activities

(a) Potatoes can either be followed by permanent grass or greenfeed barley depending upon whether the extra winter feed is required. All the potatoes are harvested in April, usually by the farm staff. Yield and price vary considerably but have been assessed at 8 tons of table potatoes and 4 tons of seed potatoes returning £18 and £24 per ton, respectively.

(b) Wheat has not been grown on this farm but the expected yield would be 70 bushells per acre.

(c) The rich, fertile soil can grow very high yielding fodder crops so sugar beet could be expected to yield 20 tons of clean, topped beet and 14.4 tons of edible tops per acre.

(d) Choumoellier can be fed off in either the autumn or winter so two activities are included in the model, the autumn fed crop yielding 60 and the winter fed crop yielding 72 tons per acre. Autumn choumoellier is cut and fed by hand, thus raising the April and May dairy labour requirements to a high level.

(e) Mangolds are normally reserved for spring feeding and yield 80 tons per acre.

(f) Swedes yield 50 tons per acre.

(g) All of the arable grazing is on the home farm and it yields more grass than does the non-arable run-off.

(h) Lucerne hay can be fed in any of the three feeding periods considered and so three identical activities have been included, one for each period.

(i) The dairy herd activity is built up in terms of ewe equivalents. This is an unsatisfactory procedure, particularly for feed requirements, but the lack of data precluded more exact estimates. It was also decided to ignore the feed requirements of the 5 or 6 winter milkers because of the difficulty of estimating their requirements.

(j) The wether activity was included because it has low labour requirements.

7.10.2 Gross Margins

The gross revenue, variable costs and gross margins are listed in Appendix II.

7.10.3 Resource Supplies and Constraints

The constraints imposed on the activities are discussed below.

(a) Labour

The permanent labour available in April and May was set at 936 hours and 800 hours respectively. This represents long hours of work and is due to the high labour requirements of the dairy herd and the potato enterprise in these months. For each of the remaining 10 months labour availability was set at 670 hours.

(b) Land

The 130 acres of arable land is considered suitable for all crops and grazing while the 30 acre run-off is only suitable for grazing.

(c) Crop Restrictions

Potatoes are restricted to 4 acres because of market limitations. One-third of the farm area (43 acres) could be sown to wheat while one-fifth (26 acres) could be sown to sugar beet. Sugar beet was limited to 26 acres because of a possible build up of soil-borne diseases, since the farm has been cropped with swedes and mangolds for many years. This restriction could be relaxed if there was no possibility of disease. Lucerne is limited to 5 acres.

(d) Feed Reconciliations

Feed requirements and supplies are given in terms of ewe equivalents. A grazing reconciliation is necessary in this model to ensure that a minimum area of grass is available. The model could, in the absence of this restriction, produce a plan in which the stock are completely fed on crops. A carrying capacity limit of 1 cow (6 ewe equivalents) per acre has been imposed. A constraint requiring hay to be supplied to the stock has not been included in this model. (The model in section 7.10.5 requires hay to be supplied and includes four hay purchasing activities.)

7.10.4 Initial Solutions

Three plans, shown in Table 7.13, have been derived. Plans 2 and 3 utilize zero per cent and 100 per cent of tops, respectively, while Plan 1 attempts to reflect present policy, sugar beet and wheat being reduced to zero.

A comparison of Plans 3 and 1 shows that the growing of 26 acres of sugar beet increases farm revenue by £1,053. This requires an annual increase of 285 hours of labour. When these figures are adjusted for the different overheads they become £632 and 324 hours respectively, which is an extra return of £1.95 per hour.

The net value of the tops is £225.

The gross margin stability limits show a wide range. However, the calculated gross margins of £115.27 for the potatoes plus greenfeed activity (P_2) and of £75.64 for the dairy activity (P_{14}) are close to their respective lower limits of £114.2 and £74.0. This indicates that a slight change in these gross margins would change the plan.

The shadow prices of potatoes (P_1) and of wheat (P_3) are £1.1 and £1.0, respectively, in all plans. These low values indicate that these activities could be forced into the plan with only a slight decline in revenue. The shadow prices of swedes, mangolds, lucerne and wethers are high and show that these activities would reduce income substantially if they were included in the farm plan.

TABLE 7.13

ACTIVITY LEVELS - CASE FARM 3

Activity	Units	Plan 1	Plan 2	Plan 3
Potatoes and greenfeed	1 acre	3	3	2
Sugar beet	1 acre	0	26	26
Winter Choumoellier	1 acre	7	6	2
Autumn Choumoellier	1 acre	4	3	2
Arable grazing	1 acre	116	92	98
Non-arable grazing	1 acre	30	30	30
Dairy	1 E.E.	877	731	764
Revenue	£	6839	7659	7892

<u>Note</u>: All figures rounded

These results show that sugar beet is a profitable crop on this dairy farm but that there is competition between the potato, wheat and dairy enterprises. Small relative gross margin changes for these activities could change the plan markedly but sugar beet would not be displaced.

Compared with present farm policy, as outlined in section 7.8, Plan 1 has a higher carrying capacity, a different cropping pattern, and gives a greater return. These differences may be due to the following factors.

(a) The input-output coefficients may be in error. These errors, if present, will most probably be found in the feed requirements of the stock and the feed supplied by permanent pasture. These latter coefficients are modified in section 7.10.5.

(b) The farmer is not using optimum plans. This is probably the main reason that Plan 1 deviates from the present actual farm plan. The 30 acre run-off has only been purchased recently and has not been fully integrated into the farm plan. Also the stock are probably being "luxury fed" at present and, therefore, carrying capacity could be higher.

(c) Plan 3 does not produce any hay.

Although it may be possible to operate the farm without hay, provided ample autumn saved pasture was available, most farmers would wish to feed some hay to the stock during the winter months. If lucerne hay was grown, carrying capacity would decline slightly, less choumoellier would be grown and revenue would decline significantly[13]. The purchase of lucerne hay would reduce the gross margin of the dairy enterprise to £74.14 which is only slightly above its lower limit of £74.0. Thus hay could be provided (by purchase) without changing the plan, although the plan becomes extremely sensitive to dairy gross margin changes.

(d) The farmer may not be willing to grow only choumoellier for supplementary feeding because the crop is difficult to feed, <u>in situ</u>, without wastage and requires a large input of labour if it is cut and fed in another paddock. Swedes, however, can be fed off successfully in breaks and the owner may prefer to grow a high proportion of them in place of choumoellier. Because swedes have a lower yield than choumoellier on this farm, 10 acres of swedes would be required to replace 7 acres of winter choumoellier. This change would decrease carrying capacity and revenue and the supplementary feed available would be:

3 acres greenfeed barley
4 acres choumoellier
10 acres swedes

This cropping plan more nearly approaches present policy except for the mangold crop.

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(13) The shadow price of winter lucerne hay (P_{11}) is £29.8 per acre.

(e) Mangolds are not grown.

The plans derived all show summer feed in disposal, that is, more feed is grown in the September-December period than can be utilized by the stock. Therefore, mangolds do not enter the plan because they provide feed in this period. They are probably grown as an insurance against a severe winter and a late spring. (On this particular farm, surplus mangolds are sometimes sold.) Some mangolds could substitute for swedes but again the labour required for feeding would place limits on their use. However, if 2 acres of swedes were replaced with 2 acres of mangolds a plan similar to that actually used would be obtained. This plan would have a lower carrying capacity and reduced revenue compared with Plan 1. Revenue would be further reduced if casual labour had to be hired for thinning and weeding fodder crops.

It may be argued that these cropping considerations are the real constraints and should be incorporated into the model. However, if this is done the problem is so restricted that the programming is less informative - its main purpose would be to provide the shadow prices. When farmers are confronted with the total revenue foregone from present plans, they may consider new methods and techniques to overcome possible difficulties. The linear programming method enables farming rules of thumb to be critically examined and appraised. Therefore, the basic model has been retained for parametric programming.

7.10.5 Parametric Solutions

The computations were again carried out in a similar way to those of section 7.5.5. From the results of section 7.10.4 it was clear that only April and May labour availability limit farm plans. Therefore, the remaining 10 labour constraints were eliminated. Labour availability for April and May was set at 670 hours and labour supplying activities at 10/- per hour included for these two months. These activities have the same interpretation as before. Three lucerne hay buying activities at £10 per ton were included, one for each of the feeding periods. So that a cheaper form of hay for winter feeding could be provided a winter meadow hay buying activity at £7.5 per ton was also added.

A hay constraint was included to ensure that a minimum quantity of hay was provided for the stock and also a maximum of 25 tons (present production) was set on hay purchases. Except for these deletions and additions, the basic model remained the same as in section 7.10.4.

Four variations of this model were parametrically programmed. Plans 4, 5 and 6 (Table 7.15) have been derived from the basic model. Because the potato enterprises demand a large input of labour these two activities were eliminated in the derivation of Plans 7, 8 and 9. Since the feed supplied by pasture could be in error the coefficients in both the arable and non-arable grazing activities were reduced(14) and the adjusted model programmed again. Plans 10, 11 and 12 (Table 7.16) were derived when potatoes were included and Plans 13, 14 and 15 when potatoes were excluded from this latter model.

These variations are summarised in the following table.

TABLE 7.14

PROGRAMMING VARIATIONS - CASE FARM 3

Variations	Plans	Solution
Basic Model	4, 5, 6	A
Basic Model with potato gross margins reduced to zero	7, 8, 9	B
Adjusted model (grazing output coefficients reduced) with potatoes included	10, 11, 12	C
Adjusted model with potatoes excluded	13, 14, 15	D

(14) See Appendix III.

TABLE 7.15

RESULTS OF SOLUTIONS A AND B - CASE FARM 3

Activity	Units	Solution A			Solution B		
		Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9
Potatoes and greenfeed	1 acre	4	4	4	-	-	-
Wheat	1 acre	0	0	0	0	0	0
Sugar Beet	1 acre	0	24	26	0	24	26
Winter choumoellier	1 acre	7	3	2	8	3	3
Autumn choumoellier	1 acre	1	0	0	1	0	0
Arable grazing	1 acre	118	99	98	121	103	101
Non-arable grazing	1 acre	30	30	30	30	30	30
Dairy	1 E.E.	883	774	765	903	794	786
Winter lucerne - buy	1 ton	0	0	1	0	0	1
Autumn lucerne - buy	1 ton	13	12	11	14	12	11
April labour supply	1 hour	390	416	418	64	90	92
May labour supply	1 hour	50	78	80	64	93	95
Revenue	£	6700	6707	7754	6543	6551	7597
Sugar Beet Gross Margin	£	33.2	33.7	73.95	33.2	33.7	73.95
Wheat Gross Margin	£	36.9	36.9	36.90	36.9	36.9	36.9
Wheat Shadow Price	£	0.5	0.5	0.5	0.5	0.5	0.5
Sugar Beet G.M. Limits: Lower	£	-	33.3823	33.8109	-	33.3823	33.8109
Sugar Beet G.M. Limits: Upper	£	33.3822	33.8108	∞	33.3822	33.8108	∞

Notes: 1. All plans utilize 100 per cent of the sugar beet tops.

2. All figures, except sugar beet gross margin limits, rounded.

TABLE 7.16

RESULTS OF SOLUTIONS C AND D - CASE FARM 3

Activity	Units	Solution C			Solution D		
		Plan 10	Plan 11	Plan 12	Plan 13	Plan 14	Plan 15
Potatoes and greenfeed	1 acre	4	4	4	-	-	-
Wheat	1 acre	0	9	16	0	12	18
Sugar Beet	1 acre	0	0	26	0	0	26
Winter choumoellier	1 acre	8	8	2	9	8	3
Autumn choumoellier	1 acre	3	3	1	3	3	1
Arable grazing	1 acre	115	106	81	118	107	82
Non-arable grazing	1 acre	30	30	30	30	30	30
Dairy	1 E.E.	870	822	667	890	824	673
Winter lucerne - buy	1 ton	0	0	0	0	0	0
Autumn lucerne - buy	1 ton	13	12	10	13	12	10
April labour supply	1 hour	380	341	338	54	0	0
May labour supply	1 hour	39	0	0	54	0	3
Revenue	£	6606	6607	7674	6447	6448	7516
Sugar Beet Gross Margin	£	0	32.7	73.95	0	32.7	73.95
Wheat Gross Margin	£	36.7	36.9	36.9	36.7	36.9	36.9
Wheat Shadow Price	£	0.1	-	-	0.1	-	-
Sugar Beet G.M. Limits: Lower	£	-	-	32.8849	-	-	32.8865
Sugar Beet G.M. Limits: Upper	£	-	32.8848	∞	-	32.8864	∞

<u>Notes</u>: 1. All plans utilize 100 per cent of the sugar beet tops.

2. All figures, except sugar beet gross margin limits, rounded.

The results are tabulated in Tables 7.15 and 7.16. From Table 7.15 it can be seen that sugar beet enters solutions A and B in exactly the same way. Wheat is always excluded but since its shadow price is so low it could enter all plans with a very slight decline in revenue.

Solution A is illustrated in Figure 7.9 and shows the changes in plan as the sugar beet gross margin is raised from zero to £73.95 per acre. (Solution B has the same general form.) There are two stable plans (Plans 4 and 6) and one very unstable plan (Plan 5) when the sugar beet gross margin lies between £33.3823 and £33.8109. The gross margin must decline to £33.8108 before less than the maximum acreage will be grown and it will remain in the plan over a wide range of price and yield combinations.

Table 7.16 shows that sugar beet enters solutions C and D at its maximum acreage when the gross margin exceeds £32.8848 and £32.8864 per acre, respectively. The acreage of wheat increases as the gross margin of sugar beet rises and hence as the acreage of sugar beet increases. This is an example of a complementary relationship and arises because sufficient labour is released from the dairy enterprise to permit sugar beet and wheat growing to increase together. However, the gross margin of wheat is near its lower limit and, as shown in Plans 10 and 13, is excluded when its gross margin falls to £36.7 per acre.

Plans 11 and 12 of Solution C are illustrated in Figure 7.10. Plan 10, of course, is derived when the sugar beet gross margin is reduced to zero and that for wheat parametrically varied and so does not appear in Figure 7.10. (Solution D has the same general form.)

As noted in the previous section, the gross margin of the dairy enterprise is close to its lower limit. This means that any change in the structure of this activity which decreases its efficiency may cause the plan to change. Thus when the pasture production coefficients are reduced the plan changes to permit wheat production, in Plans 11, 12, 14 and 15, increased acreages of chou moellier in

Fig. 7·9 Parametric Solution A - Case Farm 3

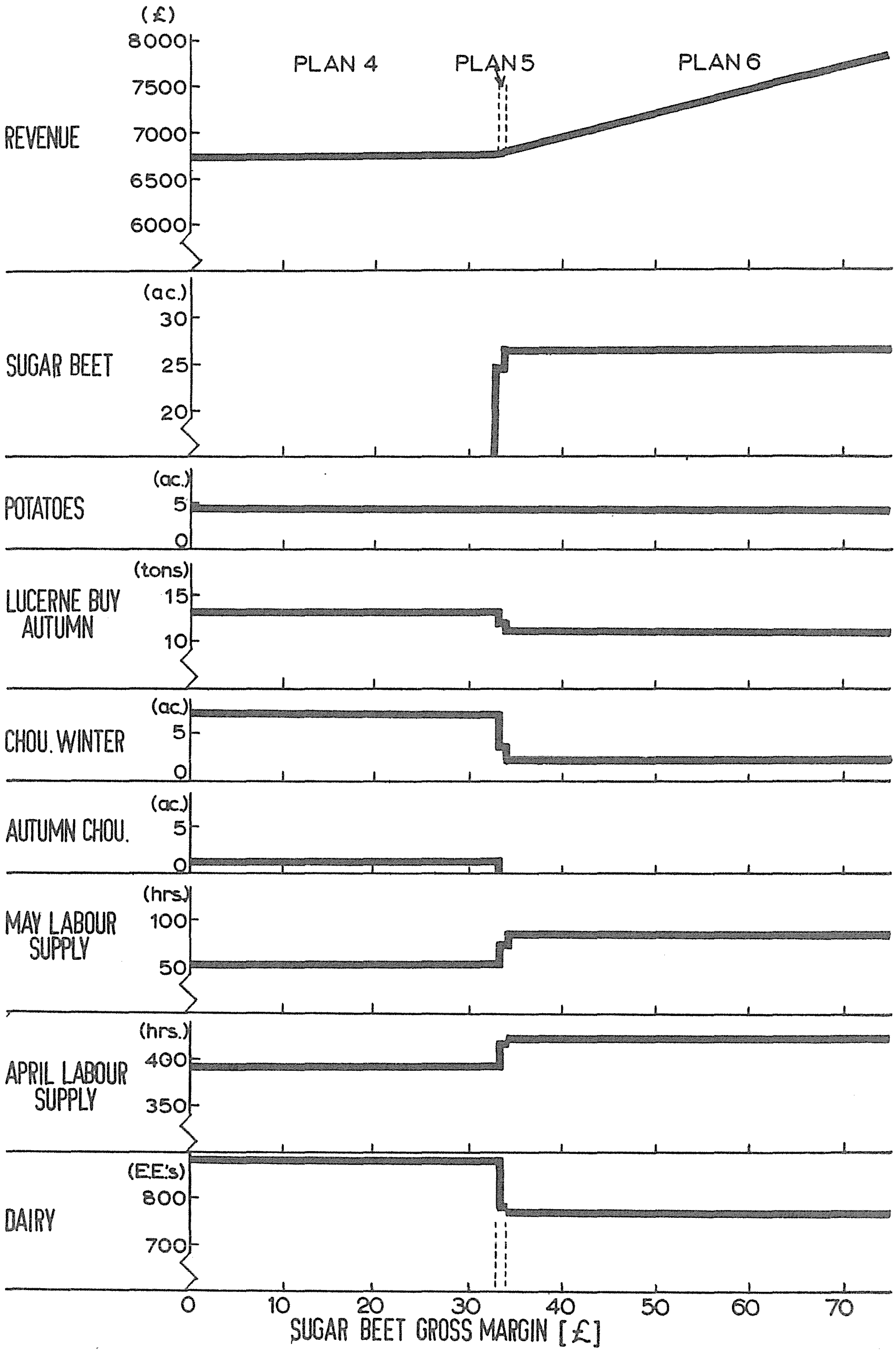
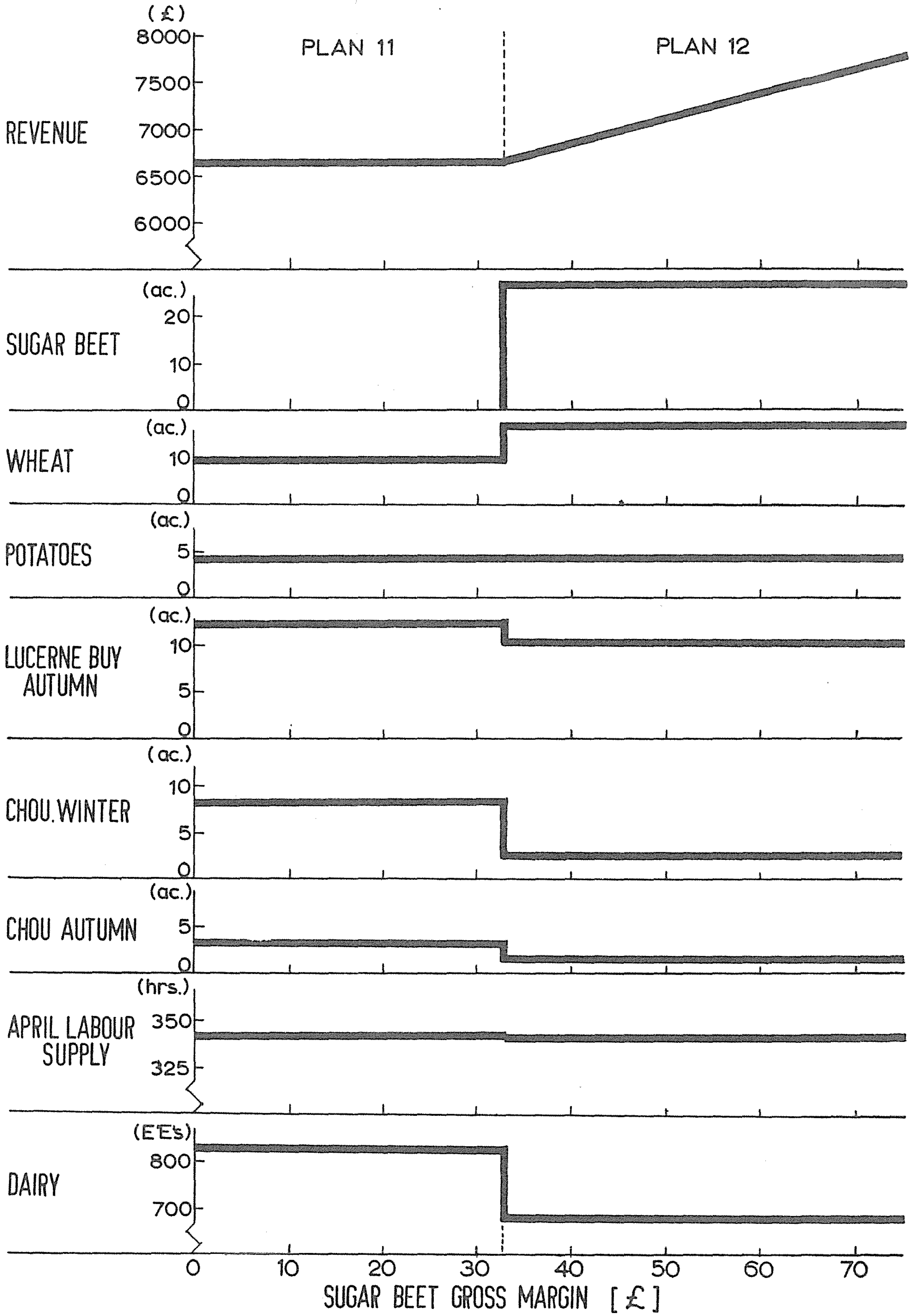


Fig. 7·10 Parametric Solution C - Case Farm 3



Plans 10, 11, 13 and 14 and a marked reduction in dairying in Plans 12 and 15 with the introduction of 26 acres of sugar beet. All of these changes take place in C and D with less than £100 reduction in revenue compared with the corresponding plans in A and B. This emphasises that small changes in the dairy enterprise can lead to marked changes in plans with little change in revenue.

The elimination of potatoes reduces revenue by less than £160 but reduces the April labour requirements by approximately 380 hours in all plans. May labour inputs are increased by approximately 15 hours. Thus the extra return per hour is £0.44, which may not be considered sufficiently remunerative for the time and worry involved in the potato crop. If, however, larger acreages were grown and modern digging machinery purchased the returns to labour could almost certainly be improved at the assumed prices.

Table 7.16 also indicates that April and May labour requirements decline as wheat and sugar beet are introduced and revenue increases. Thus wheat and sugar beet growing can reduce the peak labour demands.

Significant decreases in revenue will occur if swedes and mangolds are substituted for choumoellier and if lucerne hay is produced. Further, the revenue earned is not sensitive to the pasture output coefficients because the wheat activity will enter the plan as these are reduced.

7.10.6 Summary

The important results are presented in Table 7.17.

The results show that sugar beet is a profitable crop for inclusion in the dairy farm plan, especially if the tops are fully utilized. The actual plan obtained is, however, extremely sensitive to changes in the gross margins, or efficiencies, of the dairy and wheat activities. It is also highly dependent on the assumptions that are made with respect to April and May labour. Since this farm (and most of the dairying district) is close to sources of casual labour, it is reasonable to suppose that labour could be obtained at 10/- per hour in the autumn. If the potato enterprises are excluded, the casual labour required is very much less.

TABLE 7.17

SUMMARISED RESULTS

Plan	Wheat (acres)	Potatoes (acres)	Sugar Beet (acres)	Tops Used	Revenue (£)
Results from 7.10.4:					
1	-	3	-	-	6,741
2	0	3	26	Zero	7,148
3	0	2	26	100%	7,373
Results from 7.10.5:					
6	0	4	26	100%	7,235

Notes: 1. Revenue comparisons can be usefully made only between section 7.10.4 and solution A of section 7.10.5, because of the changed conditions in solutions B, C and D. However, the results from the two sections shown in Table 7.17 are not exactly comparable because some labour is supplied at 10/- per hour and hay is purchased in section 7.10.5, while labour is not supplied and hay is not required in section 7.10.4.

2. The revenues shown have been adjusted for the different fixed costs of each plan.

The discussion above serves to illustrate the power and versatility of linear programming methods in the exploration of dynamic farming situations. Irrespective of whether sugar beet is considered or not, the following farm management suggestions can be made.

(a) The growing of lucerne hay on this rich fertile land is uneconomic unless the purchase price of hay becomes very high. September-December feed is in disposal in all plans so this should be saved as meadow hay and further requirements purchased. (It also suggests that sugar beet pulp could possibly be used to advantage.)

(b) The greater use of choumoellier is worth consideration where crop yields approximate those used here.

(c) If a dairy enterprise is operating at a lower efficiency, under similar conditions to the one described, wheat growing may be advantageous.(15) Lower efficiency could be due to poorer quality cows, lower producing pastures, a severe labour shortage or a lower factory payout for dairy produce. If any of these factors operate, either singly or in combination, then it may pay to introduce a wheat enterprise. Wheat growing would enable a more rapid improvement of pasture quality, permit the severe culling of the dairy herd and reduce the labour input all with little loss of revenue. If sugar beet is also considered the strength of this argument is increased.

The sensitivity of the farm plan to small price or yield changes is in marked contrast to the plans for Case Farms 1 and 2 which gave some very stable plans. It is clear, however, that sugar beet production (given the assumptions made) can increase farm revenue on Case Farm 3 over wide gross margin ranges, but to a lesser degree than on the two sheep farms.

7.11 FIXED COSTS AND TAXATION

The analyses up to this point have not taken full account of fixed costs or the impact of taxation on the increased earnings from more intensive cropping. An illustrative example is presented below for each case farm taking account of regrassing costs, fixed costs and taxation. In each instance the most profitable

(15) If, for any reason, good yields of wheat could not be obtained, this argument is invalid, but with modern techniques of weed spraying, disease control and grain drying, good crops may be expected.

farm plan has been chosen from the previous analyses and compared with the plan representing present policy.

TABLE 7.18

NET INCOME COMPARISONS

	Case 1	Case 2	Case 3
	(£)	(£)	(£)
Highest programmed revenue	9,142	10,280	7,892
Cost of regrassing	345	536	231
Revenue net of regrassing	8,797	9,744	7,661
Fixed costs[(a)]	2,625	2,575	2,725
Revenue net of fixed costs	6,172	7,169	4,936
Social security and income tax[(b)]	2,845	3,472	1,920
Revenue net of tax	3,327	3,697	3,016
Revenue from present plan	6,549	6,168	6,839
Cost of regrassing	106	221	98
Revenue net of regrassing	6,443	5,947	6,741
Fixed costs[(a)]	2,400	2,350	2,500
Revenue net of fixed costs	4,043	3,597	4,241
Social security and income tax[(b)]	1,420	1,115	1,455
Revenue net of tax	2,623	2,482	2,786
Additional tax payable	1,425	2,357	465
Extra tax as % of extra revenue	66	66	67
Net gain from cropping	694	1,215	230
Net gain as % of extra revenue	34	34	33

(a) These costs include: rates, insurance, interest actually paid, wages to permanent labour, car and truck expenses, depreciation and repairs and maintenance not included in the models (fencing, buildings, etc.).

(b) The tax has been calculated from the Inland Revenue Department's provisional tax tables for the 1962-63 year using M2, M3, and M4 tax codes for Case Farms 1, 2 and 3, respectively.

Although the examples in Table 7.18 are only illustrative and depend upon the conditions stated, they do show the likely position under the present taxation legislation on highly developed, efficiently managed farms of the type described. It is clear that higher tax payments will absorb the greatest share of the increased revenue on all three farms. The net gain from cropping is very much less on the dairy farm because sugar beet does not increase revenue to the same extent. This is because of the more severe restriction on sugar beet acreage and the greater relative profitability of competing enterprises. Although the income from the dairy farm shown in Plan 1 is higher than that actually obtained by the owner it seems clear from Table 7.18 that the optimum plan including sugar beet would probably increase revenue, after the payment of taxes, by about £230.

The fixed costs of sugar beet plant and machinery reduce the relative profitability of the crop on the dairy farm. This machinery would also be used for other fodder crops, but there may be a good case for the joint ownership of this equipment where several neighbouring farmers are growing relatively small acreages. This would spread the overhead costs over a larger area and thus reduce unit costs.

On sheep farms the additional taxable revenue from intensive sugar beet and wheat cropping is substantial but only a little more than one third is left to the owner as a reward for the increased inputs of labour and management. Managerial problems will be very much greater under an intensive cropping system and these high tax payments may act as a strong dis-incentive to large scale sugar beet production. The additional returns to labour calculated earlier will be reduced by two-thirds and if extra overhead labour is included the additional return may fall to a relatively low figure.

On efficiently managed small farms where revenue is relatively low the impact of taxation on increased earnings from sugar beet production would be less than that shown above.

The effect of adding a married man to the permanent labour force on Case Farms 1 and 2 is shown in Table 7.19. It is assumed that the tax deductible fixed costs associated with the man amount to £1,500 per year.

Table 7.19 shows that more intensive cropping would pay for the annual costs of a married man and add to the revenue, after tax, of Case Farms 1 and 2. The employment of an additional labour unit would enable the owner to concentrate on farm management and business organization. Provided labour was available and farmers were willing to employ more men, this type of finding may induce the more progressive sheep farmers to grow sugar beet.

TABLE 7.19

NET INCOME COMPARISONS AFTER THE ADDITION OF A LABOUR UNIT

	Case 1	Case 2
	(£)	(£)
Programmed revenue net of fixed costs	6,172	7,169
Labour costs	1,500	1,500
Taxable revenue	4,672	5,669
Social Security and Income Tax	1,836	2,459
Revenue net of tax	2,836	3,210
Present revenue net of tax (Table 7.18)	2,623	2,482
Additional tax payable	390	1,344
Extra tax as % of extra revenue	64.5	65
Net gain from cropping	213	728

The results of the linear programming analyses were discussed with the owners of each farm in April 1964. Both sheep farmers considered that the plans derived were physically feasible. Neither, however, would be prepared to crop as intensively as suggested above and both thought that the high rates of taxation would be a strong dis-incentive to sugar beet production. They would not be prepared to work the extra hours involved in intensive cropping and both doubted the feasibility of obtaining enough labour to make this possible on many farms in the district. One farmer would be prepared to grow a small acreage of sugar beet but the other would not commit himself at this stage.

The dairy farmer thought that the carrying capacity of his farm could be raised to the levels suggested if a herringbone milking shed was built. He would be willing to grow 26 acres of sugar beet and thought that choumoellier would supplement the fodder from the tops but he would still grow mangolds for late winter and spring feed. He agreed that lucerne was uneconomic on the home farm and that potatoes were a doubtful proposition.

7.12 SUMMARY

In this chapter, the conditions under which sugar beet would be a profitable crop on three South Otago farms have been defined. The analyses are dependent on the assumptions made and must be carefully interpreted where the circumstances differ.

The assumptions made about the sugar beet enterprise, particularly, yields, price and labour requirements, are subject to error but are thought to be realistic in the light of the information available. A discussion of the work required to confirm or revise these estimates is presented in Chapter 8.

The technique of linear programming has enabled farm plans to be derived which optimise farm revenue under the constraints imposed. Parametric gross margin programming has shown how the plans change as the gross margins of sugar beet and wheat rise. The results indicate that sugar beet and wheat in combination, could raise the present level of farm incomes considerably. Some casual labour may be necessary in certain months to operate these plans depending on the hours the permanent staff is prepared to work and the amount of overhead labour required. The additional returns to labour (before tax) are high for the optimum plan on all farms.

The optimum plans for each Case Farm indicate that the maximum permitted acreages of sugar beet should be grown. However, plans appropriate to any particular set of constraints could be derived from the basic data. It seems clear that wheat and sugar beet would always exhaust the maximum cash cropping acreage on Case Farms 1 and 2. Sugar beet would be grown on all farms at its maximum acreage, while wheat would probably not be grown on Case Farm 3.

Taxation has been shown to absorb nearly two-thirds of the increased revenue on all farms and may be a serious dis-incentive to sugar beet growing.

The implications of these analyses are further discussed in Chapter 8.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 THE ASSUMPTIONS MADE

A brief review of the plausibility of the most important assumptions made in the preceding analysis is now presented.

8.1.1 The Sugar Beet Enterprise

Few, if any, of the coefficients derived for the sugar beet activity can be adequately checked either by the study of experimental results or by the experience of farmers. If the assumption of complete mechanization of spring work cannot be sustained in practice, then the labour coefficients for October, November and December will be too low. However, the results of this year's (1963-64) trials are encouraging and it seems possible that, with skilled management, thinning and weed control can be carried out without hand work. This needs to be checked over a number of seasons, together with the other cultural requirements of the crop.

The assumed average yields are based on the results of small scale trials conducted over only two seasons. These figures cannot be taken as accurate estimates of average farm yields. The linear programming analysis, however, has shown that sugar beet is a profitable crop over a wide range of gross margins. The average yield could decline by more than 3 tons per acre on Case Farm 2 (at £5 per ton) before sugar beet would leave the plan. Although the plans are relatively insensitive to the average yield figure it is essential to have reliable knowledge of the average yield and its variance before farmers could be advised to grow the crop on a large scale. The variable costs of growing the crop are high, £39 per acre on Case Farm 2, so that losses could be high if yields were low.

8.1.2 Labour Requirements and Availabilities

The difficulty of estimating labour coefficients has been comprehensively discussed in Chapters 6 and 7. The labour coefficients derived for the cropping activities are based on farmer estimates, checked as far as possible with published data, and apply to average to good climatic and soil conditions. The livestock requirements are subject to considerable variance, particularly in the sheep enterprises. The difficulty of allocating overhead labour in this study has led to the method of judging the feasibility of a plan by examining the amount of labour in disposal in each month. The plans derived appear to be feasible provided farmers are prepared to work longer hours in most months of the year than they do at present.

It has been assumed, in all cases, that wheat is harvested by contract and is not mechanically dried. When large acreages of wheat are being grown, individual farmers may wish to purchase header harvesters, grain driers and invest in storage silos. If this occurs the labour requirements for the wheat activity would change markedly during February and perhaps March as would the gross margin for wheat.

Another factor of some importance is the farmers attitude to employing more permanent labour. The returns from intensive cropping would enable this to be done at little cost to the owner because of the high rates of taxation applicable and possibly free him from much of the routine farm work and allow him to give more attention to business management.

No account has been taken of the possibilities of feeding sugar beet pulp on the farm. This is another topic which needs investigation but is beyond the scope of the present study. However, it can be seen that the addition of a cattle enterprise using concentrate feeds would considerably alter the labour requirements.

8.1.3 Feed Supplies and Requirements

These coefficients have been assessed in terms of ewe equivalents and apply to a "normal" season. They appear to be reasonable but cannot be checked from available data. The feed available from sugar beet tops depends upon yield, spoilage and the utilization rate.

8.1.4 Costs and Prices Used

All costs and prices used are those applying in the 1962-63 season. As these change the relative profitability of the enterprises will change. For example, the currently higher wool prices (1963-64) will increase the gross margins of the sheep activities. The return of £5 per ton for sugar beet was the price offered farmers in 1963 by the South Otago Sugar Beet Investigation Company. The implications of this offer are examined in Appendix IV.

8.1.5 Present Levels of Efficiency

The calculations are based on present farm management practices and efficiency levels. With the partial exception of Case Farm 3, no attempt has been made to consider the use of management techniques which would improve the efficiency of the present enterprises. Most farmers considered that stocking rates could be raised significantly if more fertilizer was applied and satisfactory labour was available. Farm Advisory Officers also said that present output could be raised substantially with the application of present knowledge.

8.1.6 Summary

It is clear from the previous sections that knowledge of the husbandry requirements and average yields of sugar beet under South Otago conditions is extremely limited. Becuase of the large amount of capital required for investment in both farm machinery and factory plant and buildings[1] it is imperative that further experimental work be conducted over a number of years. Present knowledge is insufficient to make sound decisions, particularly if the industry is to be based exclusively on beet as a source of raw material.[2]

8.2 THE RESEARCH WORK NEEDED IN SOUTH OTAGO

The main topics on which further research is required are listed below.

8.2.1 Soils

The most urgent need is to have an accurate estimate of the area of suitable soils. It is generally agreed that the soils of South Otago have limitations but there is no agreement as to the exact effect of these limitations upon sugar beet production. There are eleven main soil types to be considered. (Figure 3.1 and Table 3.2.) Varietal and manurial plot trials should be set down on each one, in each year of a five year period so that the average yields and variances may be determined.

Since six soil types constitute 76.2 per cent of the area of suitable soils within a 30 mile radius of Balclutha, as estimated by the Department of Agriculture, it would probably be sufficient to carry out the main work on them. These soils are:

	Acres
Warepa silt loam	19,500
Clydevale silt loam	15,000
Wharetoa silt loam	12,500
Te Houka silt loam	12,000
Clutha silt loam	6,000
Tokomairiro silt loam	7,000
Total:	72,000

(1) Estimates of the initial capital cost of processing facilities vary from two to three million pounds.

(2) It has been suggested that the factory be designed to process raw cane sugar as well as sugar beet - see section 8.4.2.

The Clutha and Tokomairiro silt loams are flat and intensive sugar beet production would be possible on them. The research work would not be complicated by contour problems here and the results would have more relevance to other possible beet growing districts.

The first four silt loams are hill soils with various contour characteristics. If it can be shown that two or more of these soils have similar characteristics then the experiments may not have to be repeated on each one. A thorough examination by a competent agricultural scientist is needed before this can be decided.

If an area of flat to very easy rolling country with a more uniform soil type was chosen for sugar beet production the experimental work would be much less complex.

8.2.2 Sugar Beet Culture

The best cultural methods and techniques should be determined for each soil type in the area. This should be done with large trial sites (1 to 5 acres) so that farm conditions can be simulated. Large trial sites will also enable small plot trial results to be deflated to arrive at estimates of yield under farm conditions. All of the operations detailed below should be examined over a number of years to take account of seasonal climatic variations.

(a) Autumn and winter cultivation.

(b) Fertilization.

(c) Seed bed preparation.

(d) Drilling the seed.

(e) Plant population and spacing.

(f) Thinning.

(g) Weed control.

(h) Disease and pest control.

(i) Harvesting.

(j) Strains and varieties.

Overseas experience should not be accepted until it has been checked under the conditions in South Otago.[3]

The effect on yield of various standards of crop husbandry practice should be measured. A lower standard of husbandry may be possible and profitable as long as yields are not significantly reduced. Manurial, and varietal experiments could be conducted on a plot size basis but the rest of the work must be fully mechanized so that large trial areas will be required. Plot trial work on some of the other techniques may well commence later but the most urgently needed information is data on a farm scale.

This work should be carried on in conjunction with the mechanization trials which are now described.

8.2.3 Mechanical Husbandry

The results of machinery trials are of critical importance because the crop would not be acceptable to New Zealand farmers unless it was completely mechanized. These trials would be straight forward on the two flat areas but should be designed to take account of slope on the rolling country. Preliminary work would be required to decide how this should be done but it may be necessary to carry out the work in three or four topographical situations on several of the soil types.

Several types of the machinery listed below should be used.

(a) Precision seeders

(b) Down-the-row thinners

(c) Steerage hoes

(d) Systemic granule applicators

(e) Complete harvesters

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(3) For instance, it is considered poor practice in Britain to use disc harrows because of the tendency to create minor undulations in the paddock which interfere with the efficient use of seeders and thinners. This kind of finding should be tested under South Otago conditions.

As this work proceeded accurate estimates of the time required for the various cultural operations would be obtained, together with a knowledge of the variation due to soil type and seasonal climatic conditions. This would enable the labour requirements of the sugar beet enterprise to be assessed with confidence.

In addition to determining the capabilities of mechanical thinners and weed control methods it is of great importance to discover the limitations that may be placed on the operations of sugar beet harvesters by wet autumn and early winter conditions. These limitations will be minimal on free draining flat soils but will increase as the clay content of the soil and the degree of slope increase. Harvesting in unfavourable winters overseas can present almost insuperable difficulties and reliable information should be obtained on this aspect of the crop.

If harvesting has to be completed early in the autumn and in a relatively short time, say six to eight weeks, then beet storage will be necessary both on the farm and at the factory. Beet processing should continue for 100-120 days to make factory operations economic. Thus a comprehensive study of beet clamping methods may be required. A reduced harvesting period would also increase the labour requirements of the crop in the harvest months.

8.2.4 The Place of Sugar Beet in the Rotation

Rotation experiments need to be conducted on the different soil types to determine the best place for sugar beet in the rotation. This is necessary, particularly on the rolling country where the fertility has been built up over 25 years of livestock farming. After some years of cropping the fertility may fall and yields may decline. There is little danger of this occurring on the rich and fertile Clutha soils, but some of the rolling country has been depleted in the past by excessive cereal production. Sugar beet must be integrated into the present farming system or into a new one to be evolved and the physical aspects of any changes need to be provisionally known in advance.

8.2.5 The Utilization of Sugar Beet By-products

The use of the tops and crowns has been discussed but work is needed on devising efficient means of feeding and storing them. This is especially important on sheep farms where the tops may be an embarrassment unless the livestock enterprises are reorganised to use them or they are conserved as silage. It has been assumed in the analyses that the bulk of the tops will be available from June to September. If harvesting is early and of short duration then the fresh tops will not be available during the latter part of the winter. They will keep for several weeks after harvest but not until the end of September. This emphasises the need to thoroughly investigate the harvesting procedure.

The possible use of sugar beet factory by-products on farms in the area has not been treated in this thesis. Sugar beet pulp is a valuable source of stock food and should be considered in further work. About 15,000 tons of dried pulp would be available from the factory for which there is no established market at present. Some wet pulp could be used on farms close to the factory during the processing months but it is anticipated that the bulk of the output will be dried and pelleted.

If the product can be sold at a suitable price the corral feeding of cattle should be considered. This would involve investigations into feeding methods, cattle housing and equipment, for the system would have to be mechanized before New Zealand farmers could cope with it.

8.2.6 Initial Farm Management Research

So that the possibilities of sugar beet production could be compared with the potential production and net returns from present enterprises, a farm management study should be commenced immediately. This will be complex because of the diversity of soil types and farming systems but it must be carried out before a sound decision can be made.

Initially, case farm studies should be made on farms where innovations are taking place. Linear programming as well as budgeting should be used because of its versatility and capacity for providing much useful information. With the project based in the district and continuing over a number of years data collection would become easier and sound information could be collected from co-operating farmers.

If the results of these case farm linear programming (and budgeting) studies indicated that substantial increases in production and income could be obtained from an intensification or re-arrangement of present enterprises, a comprehensive survey should be carried out to discover the potential district production. A random sample, suitably stratified by soil type and farming system should be selected. The objectives of this survey would be to find out present levels of efficiency, the possible (normative) levels of efficiency and, most importantly, whether individual farmers wished to achieve a part or all of the potential production and revenue.

This last objective is a study in rural sociology and is important in its own right, irrespective of sugar beet production. McArthur(4) has analysed the human factors which influence farm production. In the analysis he has considered sociological and psychological variables as well as economic variables and suggests that farmers are "satisfizers" rather than "maximizers". This terminology, as a broad generalization, is comparable with the difference between a "positive" and a "normative" economic analysis, since the former attempts to describe or predict actual producer responses while the latter suggests what the response should be if the producer maximizes revenue given certain constraints. It is the positive response of producers in which the policy maker or investor is interested.

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(4) McArthur, A.T.G., "Human Factors and Increased Farm Output", Proc. N.Z. Inst. of Agric. Science, 9: 201.

McArthur uses the notion of a "level of aspiration". This may be an income of £4,000, a debt free farm or any other economic, social or personal goal. The difference between the level of aspiration and the current level of achievement is termed "goal discrepancy". For example, a farmer may aim for an income of £3,000 per year. If his present income level is £1,500 then he has a goal discrepancy of £1,500. This farmer would be interested in all possible methods of increasing his income. Alternatively, if present income was already £3,000, then he would be satisfied with his present position and have little incentive to seek out or apply more intensive or new techniques.

Although this approach may not seem susceptible to precise analysis, it does attempt to treat the fundamental problem of estimating actual farmer response to a new technique. The success of such a survey is highly dependent on the skill of the enumerator in framing and asking his questions and on the articulateness of the farmer. However, it is essential to discover what proportion of farmers are dissatisfied with their present incomes and outputs and to what extent they wish to improve them. Levels of aspiration can be changed, but this is an extension problem of considerable magnitude and is not considered here.

8.2.7 Summary

It is suggested that the work listed in sections 8.2.1 to 8.2.6 would take 3 years to complete. With the results of the physical and farm management research it should be possible to make a decision on whether to pursue the project further. If the physical results and normative economic results are favourable the decision would revolve around the results of the socio-economic study. If only a small proportion of farmers wished to increase their incomes or outputs then the research programme into sugar beet should cease. If it was desired to pursue the subject further all the resources should be concentrated on devising methods of raising the levels of aspiration of producers in the district. Until this has been done adequate supplies of sugar beet will not be forthcoming, in spite of any favourable experimental or economic results.

If it was decided to continue the experimental work the following topics should be examined over the succeeding two years.

8.2.8 Trial Work and Demonstration Farms

Fertilizer and varietal trials should continue as well as cultural and mechanical trials, if necessary. Since commercial production of sugar beet would still not have commenced, the crop should be grown on two or three selected farms on a genuine farm scale. The farmers concerned should be responsible for carrying out the work as if the crop was destined for a factory. This is necessary so that farmers can observe and learn from their fellows about the crop and not be solely dependent on experimental results.

8.2.9 Extension and Further Farm Management Work

Before an attempt is made to evaluate the likely production of sugar beet every effort should be made to ensure that farmers are fully and accurately informed about all aspects of the crop as discovered by the trial results and farm management work. Frequent field days should be held during the growing and harvesting seasons.

By this time the data on the case farms should be refined and detailed and this, together with the trial data, should enable linear programming and budgeting to be carried out with confidence. (Farm management information of immense value will also have been collected on all other enterprises including alternative methods of harvesting, drying and storing wheat.) The survey farmers should again be interviewed. The enumerator will now be able to present them with several alternative ways of increasing their income or output. For example, increased stocking rates coupled with greater fertilizer usage and more subdivision, a greater wheat acreage, sugar beet or a combination of these and other methods. Full details of each method, its labour requirements, costs and returns would be provided and the farmer asked to select the method or methods he preferred and is willing to put into practice. In this way an estimate could be made of the likely tonnage of beet that would be produced. The erection of a factory should not commence before this figure is known.

Even when all the experimental and farm management work has been done and as estimate of the likely tonnage of beet made the new farm plans, which include sugar beet, are still not being actually used by farmers. The plans still have to be put into operation. This problem of executing the plan is a real difficulty which must be faced by the promoters of a sugar beet enterprise. The ability of farmers to put new plans into effect will vary. Thus field-men will be required to help and advise farmers on sugar beet growing, especially during the first few years.

8.2.10 Sugar Beet Quality

It would be desirable to conduct processing and extraction trials to check on juice purity and other relevant manufacturing details.

8.2.11 The Industry Economics

Although the methods and costs of operating and establishing a beet sugar factory are well known and overseas data would be directly applicable to New Zealand, a study should be made to check the estimates under New Zealand labour legislation and wage rates.

Since there will be approximately 250,000 tons of beet (and soil) to be transported by road and rail, a study of the transportation economics should also commence.

8.2.12 Summary

To carry out this programme of research a minimum of 5 years would be necessary. In addition to information on sugar beet a vast amount of data would become available on farming in the district which would be of immense value to extension officers and farmers. It can be seen that, as well as the evaluation of trial and economic results, it is of prime importance to assess the response of the farmers of the district after they have been fully informed of those results.

8.3 A NATIONAL SUGAR BEET RESEARCH UNIT

The preliminary results obtained in this study suggest that the project is worth pursuing experimentally so that the worth of the industry can be accurately compared with other proposed development projects. If it is decided that the prospects for a sugar beet industry should be further investigated then it would be in the national interest to thoroughly examine all potential growing districts in New Zealand so that the most suitable area or areas is selected.

So that the research work can be efficiently directed a Sugar Beet Research Unit should be set up. The South Otago Sugar Beet Investigation Company and the Taranaki Sugar Company probably have insufficient financial resources to support such a Unit so that it would need to be set up with Government financial support. The recruitment of a team of competent agricultural research workers supported by an adequate budget and working as a Unit would be one of the quickest ways of obtaining reliable data on all aspects of the proposal.

For the purpose of the following exercise it will be assumed that South Otago has been selected as the area in which to conduct the experimental work.

So that an existing administrative organization could be used the Unit would be set up as a section of the Department of Agriculture. Additional staff would have to be recruited or transferred from other work for the duration of the programme. The three key appointments would be:

(a) An agricultural crop experimentalist.

(b) An agricultural engineer.

(c) A farm management specialist, trained in modern management methods.

A tentative budget for the Unit is presented below. It is assumed that it costs about £3,000 to keep a senior research officer in the field.[5]

ESTIMATE OF THE COST OF ESTABLISHING AND MAINTAINING A SUGAR BEET RESEARCH UNIT

	£	£
ESTABLISHMENT EXPENSES		
Two heavy tractors	2,000	
One light tractor	850	
Sugar beet machinery (See 8.2.3)	4,000	
Other cultivation machinery	2,000	
Total Establishment Expenses		8,850
ANNUAL RUNNING EXPENSES		
Salaries and Allowances:		
1 Director	4,000	
2 Senior research officers	6,000	
3 General workers	3,600	
Casual labour (say)	500	
Total		14,100
Machinery Expenses:		
Maintenance and spare parts	1,000	
Fuel, etc.	800	
Total		1,800
Trial Expenses:		
Fertilizer, seed, rent, etc.		1,500
Sundries and contingencies		1,000
Total Running Expenses		18,400
Total expenses in the first year		£27,250
Expenses of remaining four years		£73,600
Total expenses of the Unit		£100,850

(5) McArthur, A.T.G., "Extension Planning", A paper given at the Advisory Officers' Conference, Invercargill, September 1963.

Let us assume the total costs are £100,000 over the 5 year period, or an average of £20,000 per year.

8.4 THE NECESSITY FOR RESEARCH

The conditions under which expenditure on research is justified are now examined.

8.4.1 A Single Purpose Factory

In the first place, Government must make a decision on whether the project is worth considering as an import saving industry. This decision may be made by ranking development projects, in order of desirability, after studies of their costs and benefits have been made. It will be assumed here that, on the basis of such a ranking, a decision has been made to seriously consider the sugar beet industry.

It is also assumed that a study of the industry economics has shown that investors in a sugar beet factory can expect a reasonable return on their investment, provided a sufficient supply of beet is forthcoming. Thus the success or failure of an industry relying on sugar beet as a raw material is assumed to be dependent on farmers growing the required tonnage of beet. (The position for a dual purpose factory is considered later.)

There are two situations facing the investor.

1. To invest in a sugar beet enterprise without doing adequate research.
2. To do the research and then decide whether to invest.

Now let P_s - probability of success, that is that farmers will grow the required tonnage of beet.

P_f - probability of failure, that is that farmers will not grow the required tonnage of beet.

G – represents the gains, as a single capital sum, both economic and social from the beet enterprise.

L – represents the losses, both the capital and the operating losses, as a single capital sum, from an unsuccessful venture.

and R_c – the present value of the cost of sugar beet research.

We now consider the expected pay-off for each decision.

Expected pay-off for decision 1. is

$$P_s G - P_f L \qquad (1)$$

Expected pay-off for decision 2. is

$$P_s (G - R_c) - P_f R_c$$

$$= P_s G - P_s R_c - P_f R_c$$

$$= P_s G - R_c \qquad (2)$$

From equations (1) and (2) we see that whenever

$$R_c < P_f L$$

research should be carried out.

Now the cost of research, as suggested in section 8.3, is £100,000 or £0.1 million.

Therefore

$$£0.1m < P_f L$$

$$\text{i.e.} \quad \frac{£0.1m}{P_f} < L$$

Table 8.1 has been prepared from this inequality.

TABLE 8.1

LOSSES (L) ASSOCIATED WITH EACH LEVEL OF PROBABILITY (P_f)

P_f	$\frac{0.1}{P_f}$ (£ million)
0.01	10.0
0.025	4.0
0.05	2.0
0.075	$1.\dot{3}$
0.1	1.0
0.2	0.5
0.3	$0.\dot{3}$
0.4	0.25
0.5	0.2
0.6	$0.1\dot{6}$
0.8	0.125
1.0	0.1

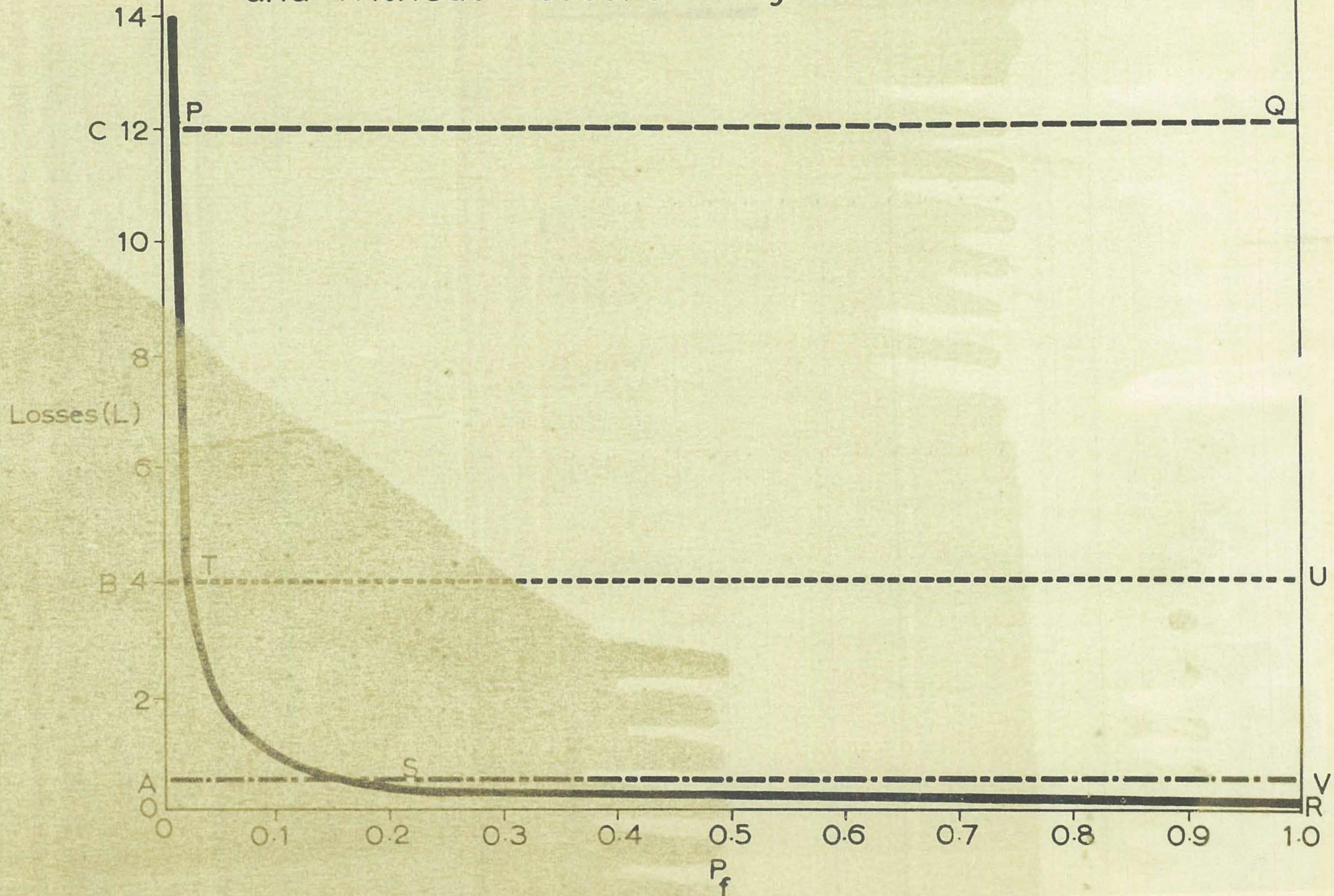
Figure 8.1 has been derived from Table 8.1. The lesser region, south west of the curve PTSR indicates where investment without research may be justified.[6] It is clear that either or both the probability of failure to obtain the required tonnage of beet, P_f, and the possible losses from an unsuccessful sugar beet industry, L, must be low before investment without adequate research could be contemplated.

8.4.2 A Dual Purpose Factory

A dual purpose factory would permit the refining of raw cane sugar as well as the processing of sugar beet. Two main advantages are claimed for a factory of this type. Firstly, operations could commence before the total

(6) Various estimates of the cost of research can be examined by drawing a series of "iso-research" curves showing the break-even position for any level of cost.

Fig.8.1 Break-even Curve Showing Where Investment with and Without Research may be Justified.



acreage of beet had been promised. This would enable hesitant farmers to evaluate the crop from the experiences of growers. If the growers were favourably impressed other farmers would seek growing contracts and the production of beet would increase. This suggestion is sound only if the probability of further production is high. If farmers experiences with the crop were not favourable production would decline, rather than increase.

Secondly, the factory could continue to operate by refining cane sugar if the production of beets declined at some time in the future. This fact may place the farmer in a situation of greater uncertainty because he may be less certain of an assured market for his beet production. If absolute protection was given to the industry this would not occur. But if the world price of cane sugar fell to a low level which enabled it to pay any "reasonable" protective tariff and still undersell beet sugar, then the beet factory would either have to reduce the price to the farmer or refine cane sugar to maintain a competitive position.

Thus when a dual purpose factory is considered, two additional factors will influence the situation.

(a) Farmers may face greater uncertainty about the future demand for sugar beet. This would probably be unimportant but, to the extent that it did occur, the probability of failure, P_f, would tend to rise.

(b) There would be an alternative use for much of the factory plant and equipment. Staff could be retained and the demand for processing raw materials (coal and lime) would continue.

Supplies of beet could also decline in the future if more profitable production opportunities became available or if present alternative product prices increased relative to that for sugar beet.

The possibility of a dual purpose factory is a very important consideration because it reduces the possible losses substantially, provided the factory is conveniently sited. It is probable that Balclutha is not a suitable site for a cane sugar refinery because it is 50 miles from a port (Dunedin) and expensive double handling would be involved. A refinery would be best sited where direct unloading from ship to refinery is possible. However, it would be physically possible to continue operations although transport charges would be high.

The possible losses will be reduced to those suffered by farmers, transportation and machinery firms. Capital and profit losses may be suffered by all three and staff reductions would probably take place. The total possible loss would be small compared to a single purpose beet sugar factory.

The effect of these factors can be illustrated in Figure 8.1. Increased uncertainty increases P_f while the dual purpose factory reduces L, say, from B to A.

8.4.3 The Position in South Otago

There are three important parameters to consider in South Otago.

1. The possible losses from a failure of the industry, L.
2. The probability of failing to secure the required tonnage of beet, P_f.
3. The cost of research, R_c.

The estimated capital costs of a factory with an output of 30-35,000 tons of refined sugar varies from 3-4 million pounds, inclusive of farm machinery and the provision of other ancillary services. If we suppose that the possible total losses are £4 million in South Otago for a single purpose factory, the region where research is required is RSTU in Figure 8.1. If the possible loss from a dual purpose factory is £0.5 million then the region of research is reduced to RSV. In this last case, the probability of success must be greater than 0.8 before research becomes unnecessary. This shows the necessity of carrying out a research programme even when the possible losses are relatively low and when the probability of success in securing adequate supplies of sugar beet is high.

If the production of 100,000 tons of refined sugar from beet is considered, the possible losses may be £12 million and the region of research is RSTPQ in Figure 8.1.

The values used above are merely rough estimates, but the position is clearly shown by Figure 8.1. As shown in Chapter 5, the probability of failure to secure an adequate tonnage of beet from the farms surveyed in this study is high. If the survey was representative of the attitude of farmers generally in the district, then the necessity for a properly designed and executed research programme is clear. After the conclusion of the work a good estimate of the acreage of beet likely to be produced should be possible and with this figure a sound decision on the feasibility of the industry could be made.(7)

8.5 CONCLUSION

This study has shown that the growing of sugar beet may raise farm revenues substantially but that the cultural requirements of the crop, under complete mechanization, are exacting. Even though the area of suitable soils in South Otago is not known with certainty, it is clear that soil type and contour will place limitations on the acreage that can be successfully grown. The usefulness of the linear programming method in exploring the problem has been demonstrated.

The worthwhileness of a sugar beet industry for New Zealand should be assessed by using a method which ranks proposed industrial development projects in order of desirability. If the project is worthy of serious consideration then an extensive programme of research is required to provide the data which is needed before a sound decision can be made.

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(7) An interesting and useful method for evaluating various investment alternatives which could be used by those with access to accurate capital and operating costs for beet sugar factories of different types and capacities is set out in the reference below.
Magee, John F., "Decision Trees for Decision Making", Harvard Business Review, July/August 1964, pp. 126-138.

Although the results of this study are only tentative it has demonstrated that more intensive cropping is profitable in South Otago. It has also demonstrated that the additional hours of work required from the permanent farm staff and the increased taxation payable would reduce farmers interest in sugar beet. If New Zealand farmers were essentially managers, as are many of their British counterparts, instead of combining the functions of managers and farm workers, then these two factors would be less important. The fact that the New Zealand farmer has to do the physical work involved in intensive crop production as well as deal with planning and management will almost certainly reduce his interest in a crop such as sugar beet.

Thus the estimate of the likely acreage of beet that will be grown in South Otago is not a pure economic and farm management problem but is a socio-economic problem where the notions of levels of aspiration and goal discrepancies have great importance. Even if a sufficiently high estimate of the beet likely to be grown is made that justifies the erection of a factory, the problem of executing the plans successfully and profitably on individual farms still remains.

Thus the following recommendations are made.

1. New Zealand should continue to purchase her supplies of raw sugar at the world price whether through an arrangement with the Commonwealth sugar producers or not.
2. The setting up of a domestic sugar beet industry should not be considered for at least five years.
3. The results of this study indicate that, at a price of £5 per ton for sugar beet, it is worthwhile analysing the farmers' side of the problem. The promoters of the industry and the Government must decide whether this price can be maintained to farmers when the world price of cane sugar is low (see Appendix IV) and whether there is sufficient farmer interest in the proposal to justify the expenditure of £100,000 on a research project.

4. If these two questions are answered in the affirmative, then the Government should set up a Sugar Beet Investigation Unit charged with the task of selecting the most suitable district (or districts) for the industry and thoroughly examining the crop husbandry, mechanical husbandry and farm management implications of the crop. This would probably take five years to complete.

5. If the preliminary results of this study were favourable then a thorough investigation of the economics of the processing industry should be commenced and the results studied in the context of a national development plan.

6. Socio-economic studies are required to make estimates of the probable acreage of beet that would be grown in any district.

7. A study should be made of any possible trade advantages to New Zealand of purchasing our supplies of raw sugar from tropical countries to whom we wish to sell our food products, particularly dairy products to Caribbean and Latin American countries.

APPENDIX I

THE TECHNICAL REQUIREMENTS OF SUGAR BEET CULTURE

The technical requirements of sugar beet production are discussed in this Appendix.

1'.1 CLIMATE[1]

The economic value of the crop depends on those physiological functions and processes that lead to a high sugar content. Yield and quality are probably affected more by water supply than summer temperatures, but autumn temperature levels have a marked effect on sugar storage. Whyte says:

> "Other results confirm the long experience of farmers with regard to the connection between night temperature and growth and sugar content; the sugar content increases with decreasing night temperatures, 7 percent at 86°F, 12 percent at 36°F. The weight of roots increases rapidly with rising night temperature, reaching a maximum between 57° and 79°F. Thus, when the beet is approaching maturity low night temperatures are economically desirable." [2]

In the northern hemisphere beet is grown throughout the temperate zone. There is considerable diversity in the climatic conditions under which crops are produced. A long growing period is desirable, with rainfall well spread, followed by dry sunny weather during the month before lifting. A properly matured beet should have a high sugar percentage, and uninterrupted growth throughout the season is essential for the plant to mature normally.

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(1) Whyte, R.O., "Crop Production and Environment", Faber and Faber, (London), 1960, pp. 248-260.

(2) Whyte, R.O., <u>op. cit.</u>, p.253.

Climatic conditions also affect the culture and handling of the crop. Winter frosts aid the formation of a fine tilth in the seed bed, which is essential for even germination. Cold conditions, however, during the first three weeks after sowing the seed are likely to induce a high percentage of bolters,(3) especially in susceptible varieties. These bolters present harvesting and processing problems as well as being low in sugar. During the growing season adequate water, either from irrigation or rainfall, is required, but dry conditions are desirable during harvesting since heavy machinery has to be used in the beet fields. Wet soil conditions can make this task very difficult and sometimes on clay soils impossible. Wet conditions also result in excessive quantities of soil adhering to the beet.

1'.2 SOIL TYPES

> "The best soil for the beet is a deep free working loam, but the crop has been grown quite satisfactorily on well drained soils of practically all types." (4)

Sugar beets are deep rooting plants and should be grown in deep soils if well shaped roots, free from fangs are to be produced. The soil should retain sufficient moisture to encourage continuous growth but not an excess which would impede spring cultivation or increase harvesting difficulties. Beet grows best on naturally fertile soils but many soils that are inherently poor chemically can often grow beet successfully if they are suitably fertilized. The power of the soil to retain moisture or to lose excessive moisture is more important than its natural fertility. Low pH levels must also be corrected for beet is an uncertain crop on acid soils. For best results major element deficiencies of potassium, phosphorus, nitrogen and sodium must be corrected as well as any minor element

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(3) Bolting occurs when the beet plant does not behave as a biennial, but sends up a flowering stem and completes its reproductive cycle in the first year.

(4) Watson and More, "Agriculture", Eleventh Edition, Oliver and Boyd, (London), 1962, p.300.

deficiencies, particularly of boron, manganese or magnesium.

The distribution of sugar beet in Britain according to soil type is shown in Table 1'.1.

The table shows that 62 percent of the beet is grown on loams and sands and only 10 percent on the clays. Beet has therefore established itself on the lighter soils and in the drier districts. This concentration of beet on the lighter soils is largely due to their ease of cultivation, for the light soils do not give the heaviest yields.

TABLE 1'.1

DISTRIBUTION OF SUGAR BEET IN BRITAIN
ACCORDING TO SOIL TYPE

Soil Type	Growers	Acres	% Growers	% Acres
Clay	3,567	41,511	9.4	10.0
Fen (Peat)	4,050	42,271	10.7	10.3
Limestone	914	15,366	2.4	3.7
Loam	17,222	189,864	45.7	45.8
Sand	4,779	66,798	12.7	16.7
Silt	4,244	24,097	11.2	5.8
Unclassified	2,989	34,333	7.9	8.3

<u>Source</u>: "Sugar Beet Cultivation", Bull. 153, Ministry of Agriculture, Fisheries and Food, (London), 1960, Table 5, p. 21.

1'.2.1 <u>Sandy Soils</u>

Sandy soils are easily worked and allow deep root penetration. Seed-bed preparation, weed destruction and harvesting of beet is easier on sands than on any other soils, but their inability to retain sufficient moisture for continuous growth keeps yields low in most seasons. Very early sowing is possible and this may, to a small extent, counter the ill-effects of later drought. Excellent crops can be grown under irrigation.

1'.2.2 The Clays

> "Soils heavier than clay loams are unsuitable for beet cultivation, even in a dry district."(5)

Undesirable subsoil is inverted if these soils are cultivated too deeply and harvesting after rain is made difficult and expensive by the sticky nature of the soil. The soil texture may be also damaged under wet conditions. Further, it may be impossible to feed off the tops directly and they would have to be carted off and fed or made into silage.

The clay loams are good beet soils in the drier areas. In wet years top growth may be excessive and lifting difficulties increased, especially as the season progresses. Thus early lifting is often necessary. To obtain good seed beds clay loams should be ploughed early and carefully worked so that the winter frost mould is kept on the surface.

1'.2.3 The Loams

A deep medium loam or silt is probably the best soil for sugar beet. These soils can retain sufficient moisture for continuous growth and yet drain quickly after rain. They have good physical conditions for beet growing and, after any nutrient deficiencies have been remedied, high yields can be obtained regularly. Stony loams, however, cause excessive wear on implements, and may make mechanical thinning and harvesting difficult.

1'.2.4 The Peats

Peats with a clay subsoil, adequately limed, yield heavy crops of a coarse beet with below average sugar percentage and a high content of nitrogenous compounds.(6) Deep peats are poor beet soils and need constant consolidation before beet will grow well.

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(5) "Sugar Beet Cultivation", Bull. 153, Ministry of Agriculture, Fisheries and Food, (London), 1960, p.22.

(6) Excessive quantities of nitrogenous compounds, termed "noxious nitrogen" leads to extraction problems in the factory. See section 1'.5.10.

1°.3 CONTOUR

The mechanization of sugar beet production requires accurate seeding, thinning and inter-row cultivation techniques.(7) Rolling country would add, to varying degrees, to the difficulty of attaining the required degree of precision. Further, areas intersected by gullies or streams would necessitate curved rows (unless considerable areas of land were not sown around the sides of the beet area), again adding to the difficulty of mechanical cultivation.

It has proved impossible to obtain any experimental data on the limitations sloping ground may place on the crop. Sugar beet is grown on rolling country in Ireland, but most of the thinning and weeding is done by hand labour. The Armer harvester was specially designed and developed for these conditions.(8) Mechanization problems will increase, as will the cost of all operations, as slope increases but the extent to which this occurs has not been reported in the literature.

1°.4 SUGAR BEET IN THE ROTATION

In Norfolk, where about one-quarter of the British sugar beet crop is grown, there has been an acre for acre substitution of beet for stock feeding roots over a thirty-five year period. Between 1925 and 1960 there was a drop of 100,000 acres in stock feeding crops and a comparable increase in sugar beet acreage without any interference with the fundamental principles of mixed farming and there is evidence to show that the interest in livestock farming has increased rather than decreased since sugar beet was introduced.(9) Sugar beet has been successfully integrated with mixed farming in all countries where it has been

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(7) It is assumed in this study that the crop must be completely mechanized before it would be acceptable to South Otago farmers.

(8) Armer, A.A., "A Harvester for Ireland's Sugar Beets", Agricultural Engineering, 34: 312, 1953.

(9) Rayns, F., "The Lord Hastings Memorial Lecture 1961", Norfolk Agricultural Station, Norwich, pp. 17-19.

introduced.

Cereal or pulse crops are considered the best crops to precede sugar beet. Cereals, since the introduction of effective weedicides, give ample opportunity for cleaning the land and both give plenty of time for early ploughing.

After a well managed pasture, the land is in good condition for beet but ploughing must be well done, otherwise uncovered turf will harrow out and cause difficulty both at drilling and hoeing. Crops fed off during winter can precede beet as long as ploughing is not too late.

Because harvesting continues into the winter, spring sown crops should follow beet. The cereals, barley, wheat or oats, are usually sown in Britain. Barley does particularly well after beet due to heavy manuring and thorough cultivation received by the beet and the feeding off or ploughing in of the tops. Thus, beet takes essentially the same place as winter roots in the rotation.

1°.5 SUGAR BEET CULTURE

A discussion of the cultural and husbandry requirements of sugar beet is presented below.

1°.5.1 Autumn and Winter Cultivations

If sugar beet follows pasture or a grain crop, ploughing should be from nine to twelve inches deep, where soil conditions permit, so that turf or crop residues can be placed well below the surface. Where beet follows a winter forage crop, ploughing will be later and seed bed preparation rendered more difficult. Deep ploughing necessitates the use of a deep-digging plough which leaves the land in good open condition to take the greatest advantage of winter frost for the provision of a fine frost mould. The additional depth of working also encourages the development of a more shapely root which is of importance at lifting. Where a clay pan is present or the soil is relatively shallow, sub-soiling will shatter the lower soil layers and allow deeper root penetration. "One way ploughing" aids the preparation of a level seed-bed since it leaves the land without ridges and furrows. In the absence of a reversible plough, it is preferable to plough round the paddock rather than in lands.

1'.5.2 The Fertilizer Needs of Sugar Beet

A well grown crop of sugar beet removes a large quantity of plant nutrients from the soil. Forty crops were examined in 1944 and 1945 in England and Table 1'.2 prepared.

The figures for phosphoric acid are less extensive, but approximately 0.36 cwt. P_2O_5 is removed by an eleven top crop - about half in the roots and half in the tops. Since average yields have increased by three to four tons of roots per acre since 1945, the uptake of nutrients will now be higher.

Table 1'.2 shows that, although the roots account for over half the fresh weight and two-thirds of the dry weight, the nutrients are mainly concentrated in the tops - especially so with sodium which is an important nutrient for sugar beet. If roots and tops are removed for the crop shown in Table 1'.2, the soil loses the equivalent (approximately) of 2 cwts. of superphosphate, 2.5 cwt. of muriate of potash and 1 cwt. of lime.

TABLE 1'.2

REMOVAL OF NUTRIENTS FROM THE SOIL

	Yield of Roots and Tops (tons per acre)		Nutrients Removed (cwts. per acre)			
Part of Crop	Fresh	Dry Matter	N	K_2O	Na_2O	CaO
Roots	11.2	2.63	0.44	0.39	0.07	0.15
Tops	10.2	1.27	0.77	1.04	0.64	0.34
Total	21.4	3.90	1.21	1.43	0.71	0.49
Tops as % of total	48	32	64	73	90	69

Source: Sugar Beet Cultivation, op. cit., Table 8, p.31

The first essential in the preparation of land for beet is to ensure that the soil contains an adequate supply of lime. Progressive loss of yield occurs as the pH falls below 6.5 and the crop will fail if the pH falls to 5.3 or less.[10] A survey in Southern Sweden showed that best yields were obtainable in the pH range 6.7 to 7.6.[11] Excessive applications of lime can result in deficiencies in the minor elements, manganese, boron and magnesium.

The fertilizer requirements of beet have been extensively studied and are well known in Britain. Heavy dressings of a compound fertilizer are invariably applied, often in addition to an application of ten to fifteen tons of farm yard manure.[12] A typical mixture for general use in a normal rotation (i.e., not out of pasture) would be:

Sulphate of ammonia	5 cwt.
Superphosphate	3 cwt.
Muriate of potash	2.5 cwt.
TOTAL	10.5 cwt.
Salt	3 cwt.

Where a good dressing of high quality dung had been ploughed in before the beet the mixture may be:

Sulphate of ammonia	4 cwt.
Superphosphate	1 cwt.
Muriate of potash	1.5 cwt.
TOTAL	6.5 cwt.
Salt	3 cwt.

In particular cases a specific dressing would be formulated for the soil type and situation concerned, but heavy dressings are the rule.

A large series of manurial trials carried out in the United Kingdom from 1940 to 1949 clearly showed that applications of common salt increased beet

(10) Tidy, D., "Use of Sugar Beet Factory Waste Lime in Yorkshire", Brit. S.B. Rev., 30(4): 183-184, 1962.

(11) Sugar Beet Cultivation, op. cit., p.32.

(12) Adams, S.N., "Present Views on Sugar Beet Manuring", Brit. S.B. Rev., 27(3): 111-113, 1959.

yields. Salt performs at least, in part, the same function as potash, since the increase in yield from salt is considerably reduced when potash is applied. Holmes[13] concludes that it is highly profitable (at British prices) to use salt on sugar beet in addition to potash on soils which are low or tending to be low in available potash. In soils high in available potash the return for using salt, in addition to potash, is unlikely to be profitable.

Germination of sugar beet is easily damaged by high concentrations of soluble salts close to the seed so nitrogenous or potassic manures should not be sown with the seed. Probably the most convenient way to manure beet is to apply 3 cwt. of salt per acre on the stubble in the autumn and 6-7 cwt. of a compound fertilizer before seed bed cultivation in the spring.[14]

1'.5.3 Seed Bed Cultivation

The sugar beet seed is more sensitive in its requirement of soil moisture for germination than that of any other temperate farm crop and as it is essential for mechanical thinning that the crop emerge uniformly this demands that seed of high vigour and germination capacity be sown at a uniform depth in a consistently moist soil.[15] Basic seed-bed preparation should be done during the winter, on the furrow, leaving only a minimum of work to do immediately before drilling. A good seed-bed should be firm and moist beneath with a fine tilth on the surface and this is best obtained by shallow cultivations confined to the weathered top soil.

While the beet crop can be grown successfully on undulating ground, minor surface irregularities can hinder and reduce the efficiency of the different cultural operations. For this reason, one way ploughing or ploughing on-the-square is being adopted and following cultivations are carefully done to preserve a level

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(13) Holmes, J.C., "Salt for Sugar Beet in Scotland", Brit. S.B. Rev., 29(4): 163, 1961.

(14) Adams, S.N., "Fertilizers for Beet", Brit. S.B. Rev., 29(4): 154, 1961.

(15) Dunn, J.S., Paper presented to the Agricultural Engineers Conference, Hastings (N.Z.), 1963, p.4.

surface. Heavy Dutch harrows, seed harrows, clod crushers and levellers judiciously used, on the furrow, should produce a good seed-bed. Care should be taken to prevent the formation of tractor wheel ruts as these interfere with subsequent hoeing and thinning operations.

Gingell[16] in describing his experiences with mechanical thinning says:

> "The field must be level. It takes considerable trouble and expense to achieve this and to ensure that subsequent cultivations do not impair it. Levelling a farm is a long term policy. The bulldozer is used freely to deal with major undulations and the landplane in conjunction with the standard mounted cultivator, after harvest (cereal), on next year's beet area. One cannot possibly do too much levelling and each time makes for some real improvement. The law of diminishing returns is slow to apply here."

1'.5.4 Drilling the Seed

In the drier beet areas in Britain, almost all beet is now drilled on the flat. This method enables better soil moisture conservation during seed-bed preparation and the rows may be closer together than is practical with a ridged crop.

The aim is to obtain a weed free braird (plant stand) with as many single plants spaced evenly and regularly along the row as possible. A spacing (precision) drill is necessary for accurate seed placement. Various mechanisms are in use and drills can be obtained which are as good in selecting and distributing single seeds as practical conditions require. This requires, however, that the speed of drilling be carefully controlled. Harvey[17] suggests that two miles per hour is ideal. To overcome the disadvantages of slow working up to twelve seeder units may be mounted on a tool bar.

Within limits the shallower the beet seed is drilled the better the germination. About three-quarters of-an-inch is considered the best depth. In drying weather or on a seed bed that has been difficult to prepare it may be

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(16) Gingell, H., "Some Experiences with Mechanical Thinning", Brit. S.B. Rev., 31(4): 187, 1963.

(17) Harvey, P.N., "Sowing and Thinning the Sugar Beet Crop", Field Crop Abstracts, 11(3): 154, 1958.

necessary to go as deep as one and-a-quarter inches to find adequate soil moisture for optimum growth.

The sugar beet "seed" is, botanically, a cluster normally containing from one to four true seeds embedded in a woody outer husk. A single cluster, therefore, produces several seedlings in a closely entwined bunch. Different forms of seed treatment have been practiced in order to reduce the average number of seeds in each cluster to aid the singling of the crop. Rubbed and graded, segmented and pelleted seed has been produced but it was not until the commercial development of the monogerm character and its incorporation into standard sugar beet varieties that a satisfactory seed was obtained for mechanical husbandry.(18) Monogerm seed, if accurately sown, will provide a high proportion of singles in the row. This seed is commercially acceptable in the United States, but the less favourable climate in Britain results in lower yields and a tendency to bolt excessively. A breeding programme will, in time, overcome these disadvantages.

1'.5.5 Plant Population and Spacing

Experimental evidence(19) has shown that the highest yields of roots are given by close spacings both between the rows and within the rows to give a plant population of approximately thirty thousand plants per acre. On very rich soils, where individual plants grow large, fewer plants will give the same yield, but on very light soils more plants will be required. One plant to 220 square inches will give about thirty thousand plants per acre but in order to allow for the inevitable gaps it is better to plan spacing at one plant per 200 square inches. An ideal apportionment of soil and light would be obtained with fourteen inch rows and fourteen inch spacings between plants in the row, but this would make mechanization impossible. In practice, the allocation of 200 square inches per

(18) "Crystal-ized Facts About Sugar Beets", 15(3): 4-29, 1961. American Crystal Sugar Company, Denver, Colorado, U.S.A.

(19) Harvey, P.N., op. cit., p.151.

plant has to be secured by sowing in rows 18, 20 or 22 inches apart and singling to intervals of 11, 10 or 9 inches respectively.[20] Wider drilling facilitates summer cultivation, saves seed and reduces the labour of singling and lifting and there may be occasions when these advantages compensate for a slightly smaller crop.

1'.5.6 Thinning the Crop

Plant numbers should be reduced to leave a regularly spaced succession of single plants. A proportion of the European beet crop is still hand thinned but mechanical thinners are being used increasingly, although hand trimming is still almost universally practised.[21] Maughan[22] reported that, in the Great Plains area of the United States, only twenty per cent of the crop was thinned by machine in 1955.

Harvey[23] distinguishes three ways of thinning the crop mechanically:

(i) Cross-cultivation

(ii) Cross-blocking and gapping

(iii) Down-the-row thinning.

Cross-cultivation with a harrow finger weeder will let light and air into an over-thick crop, but it will not avoid the need for hand singling.

Cross-blocking means drawing a set of hoes across the seed rows so that most of the plants are cut out, leaving bunches of plants in the position where a single plant is required. Gapping achieves the same result by using a machine which travels down the rows. These methods are inefficient because the braird is

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(20) Watson and More, op. cit., p. 302.

(21) Unless monogerm seed is used, mechanical thinning leaves many positions with two or more plants. Hand trimming consists of removing any excess plants and tidying up the braird.

(22) Maughan, G.L., "Precision Drilling and Mechanical Thinning", Proc. 18th Winter Congress Institut International de Recherches Betteravieres, Brussels, 1955, p.155.

(23) Harvey, P.N., op. cit., p.155.

rarely even enough and wide gaps are often left, making it impossible to attain the desired plant population. Also, if the hoeman accidentally cuts out a bunch there is no means of compensating for the error.

Down-the-row thinning can vary from merely opening up a thick crop, to the complete elimination of hand labour, but the extent to which the machine can replace hand work depends largely on the regularity of the initial seedling stand. Early in the 1950's the Windsor system was developed in the United States and has now come into general use. Plants are removed from the row by small tines mounted radially on a rotating head. Both the number and size of the tines may be varied. Two treatments at a three or four day interval are given when the plants are in the two true-leaf stage, after making plant population counts and consulting tables to determine the appropriate reduction in plant population required. The first passage of the machine cuts out 50 per cent of the plants in alternating 1.75 inch widths. The second treatment is carried out when the surviving plants are again standing up, the number of tines and width of blade used depending on the stand at that stage.

If there are numerous weeds, a preliminary operation with the thinner fitted with spring weeder heads is useful in removing small weed seedlings, which at this early stage are usually less firmly rooted than young beet plants.

A modified form of the Windsor system has been evolved in Europe where pendulum and reciprocating thinners have been developed. These are simpler and slightly cheaper than the rotary type but it would appear that their performance is not so predictable.(24)

Mechanical thinning enables the whole sugar beet acreage to be drilled early because the drilling dates do not have to be staggered to prevent the crop "growing away from the hoe" as with hand work. Irregularity of plant distribution, which is inevitable after a complete mechanical thinning operation, does increase harvesting difficulties with the result that top and dirt tares have increased

(24) Dunn, J.S., op.cit., p.3.

slightly.[25]

1'.5.7 Weed Control

The germination and emergence of sugar beet seedlings takes from 10-14 days and up to 21 days under adverse conditions. Many annual weeds germinate more rapidly and the crop is faced with early competition from weed growth. (The practice of several shallow cultivations before sowing to destroy germinating weed seedlings conflicts with the desire to conserve soil moisture and is not recommended.) If hand work is to be replaced by the machine, and particularly where precision drills and low seed rates are used, a chemical means of weed control is essential. A thick stand of beet will crowd out other seedlings but a thinly spaced crop will be quickly invaded by weeds.

Gibbon[26] in discussing weed control says that pre-emergence, non-selective weedkillers such as P.C.P. (pentachlorophenol) and post-emergence treatment with nitrate of soda or salt spray were useful stop-gap measures but neither proved entirely satisfactory. During 1960 and 1961 many trials in Britain showed that a mixture of endothal (3,6-endoxo-hexa-hydrophthalic acid) and propham (isopropyl-N-phenyl carbamate) gave good weed control under the right conditions, having a residual effect lasting from six to eight weeks. Two important facts have emerged. The rate of application is critical and varies in proportion to the silt and clay content of the soil, and rainfall of at least 1/8 inch within two weeks of drilling is required. The rates of application may be determined by a soil analysis. Since the rates of application increase with the clay content of the soil, the cost may be prohibitive on soils heavier than medium loams.

Intensive research into the development of more effective weedicides for sugar beet is being conducted in many parts of the world and improved formulations

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(25) Turner, N.V., "Mechanical Thinning Adds to Net Profit", Brit. S.B. Rev., 29(4): 165-166, 1961.

(26) Gibbon, A.W., "Band Spraying for Weed Control in Sugar Beet", Brit. S.B. Rev., 30(4): 185, 1962.

are becoming available. One which shows some promise is P.C.A. (1 - phenyl - 4 amino - 5 - chloro-pyridazone - 6). This chemical is at present being tested by the New Zealand Department of Agriculture.(27) It can be used for pre-and post-emergence control of weeds in sugar beet, fodder beet and mangolds. For post-emergence control, the crop must have passed the first true-two-leaf stage if excessive damage is to be avoided. Preliminary results show that the susceptible species include fathen (Chenopodium spp.) and that spurrey (Spurgula avensis) is resistant while cleavers (Golium oparine) and the Polygonum spp. are moderately resistant.

Inter-row cultivation will be necessary until the leafage meets across the rows and possibly some hand pulling of weeds between the plants as any weeds left, especially fathen, create added difficulties at harvest time.

1'.5.8 Pests and Diseases of Sugar Beet

Sugar beet is subject to a large number of pests and diseases, but little work has been done to determine those likely to affect the crop in New Zealand, so only a short discussion of those of potential importance is given.(28)

Virus yellows is the most important disease of sugar beet in Britain and its presence is suspected(29) in New Zealand.

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(27) Matthews, L.J., Principal Scientific Officer, Department of Agriculture, Wellington. Personal communication.

(28) Jones, F.G.W., "Sugar Beet Pests", Bull. 162, Ministry of Agriculture, Fisheries and Food, (London), H.M.S.O., 1957.

Hull, R., "Sugar Beet Diseases", Bull. 142, Ministry of Agriculture, Fisheries and Food, (London), H.M.S.O., 1950.

These publications provide a comprehensive account of symptoms and control measures to which the reader is referred for full information.

(29) Dunn, J.S., personal communication.

In the field, virus yellows has to be considered as a complex of strains ranging from very virulent to nearly avirulent. The Virus Desease Committee of the Institut International de Recherches Betterarvieres (I.I.R.B.) in their 1959 report[30] said that the several viruses that cause yellows of sugar beet in field crops can be placed into two groups. Those in Group I generally produce a severe form of the disease, but isolates from different sources can vary considerably in virulence. A milder form of yellows is caused by the viruses in Group II. They produce yellowing of sugar beet more slowly and are thought to be unrelated to Group I viruses. The term "mild yellows" is sometimes applied to this form of the disease.

The discussion below refers to virus yellows produced by the Group I viruses. Although mild yellows causes yellowing of the crop it rarely affects yield significantly.

The first symptom of the disease is a thickening of the leaf lamina followed by a yellowing of the leaf spreading from the tip. The infected leaves are brittle and when crushed in the hand crackle and break into small pieces. The disease first becomes apparent as a general paling of the crop in patches, but the extent to which the disease spreads is very variable. If the infection is widespread and occurs early in the season, the crop assumes a bright yellow colour and is so stunted that soil can be seen between the rows and weed growth may be excessive. Reduction in yield may be as high as 50 per cent. Sugar content may be reduced by one or two per cent and the processing quality of the roots may be adversely affected. Infection later in the season has a reduced effect on yield.

Beet yellows virus is introduced into the crop by the peach-potato aphid, *Myzus persicae*. The severity of attack depends upon the extent of sources of

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(30) Rietberg, H., "Virus Yellows of Sugar Beet and its Control", Proc. 22nd Winter Congress, I.I.R.B., Brussels, 1959, pp. 269-311.

virus and the numbers and behaviour of the aphid vectors. The virus is not seed borne. Seed crops of sugar beet, mangolds and red beet and mangold clamps are sources of the virus in the following year.

During mild winters the aphids persist in large numbers, not only on their chief winter hosts (savoy cabbage, turnips and other brassicae) but also on the sprouts of clamped mangolds and sugar beet seed crops. Migrants from the last two sources are the most dangerous because they may carry the virus, whereas brassica crops do not harbour the virus. In severe winters the aphid is more dependent on the eggs laid on peach trees but it may over winter in mangold clamps, gardens and other sheltered places. The black bean aphid (Aphis fabae) can spread the infection introduced by Myzus persicae. Severe virus attacks are associated with mild winters and dry hot springs and summers.

Control is assisted by the elimination as far as possible of the sources of virus, thus the seed crops should be grown in another district where pasture and cereal crops are chiefly grown. The main method of control now used is to spray with a systemic aphicide to reduce the aphid population, thus delaying and decreasing the spread of virus yellows within the crop. In Britain the factory fieldmen regularly inspect crops and if the aphid population reaches a potentially dangerous level a general warning is issued. Spraying is usually advisable when an average of more than one aphid per four plants is found.(31)

Dunning(32) in discussing the relative efficiencies of insecticides suggested that the application of the new granular systemic compounds may be more effective than sprays. The granules are sprinkled in a band above the rows of plants by means of a granule applicator mounted on a tractor hoe. This method confers a six week period of protection to the beet foliage compared to seven to twelve days following spraying.

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(31) Dunning, R.A., "Aphids and Yellows in 1960 and Prospects for 1961", Brit. S.B. Review, 29(3): 118, 1961.

(32) Dunning, R.A., "Insecticides to Control Aphids and Yellows", Brit. S.B. Rev. 30(3): 133-135, 1962.

The frequent cropping of land with sugar beet or mangolds is liable to lead to a condition known as "beet" or "mangold sickness", in which the plants are stunted and the yield very seriously reduced. This condition is caused by the beet eelworm (Heterodera schachtii, Schm.) a common pest in Europe and the United States and one of the major problems wherever beet is cultivated intensively. The eelworm has not been positively identified in New Zealand to date but is a potential source of trouble to a beet industry.[33] Clarke states that it is a prime requisite to know whether this pathogen is present before a beet industry is established.[34]

The life cycle of the eelworm takes place entirely below the surface of the soil and injury to the sugar beet or mangold plant is caused by eelworms feeding within the rootlets. A few eelworms are unnoticed and it is not until the population in the soil becomes high, because of over-cropping, that injury becomes apparent to the farmer. The appearance of the disease in patches in a field is a warning that susceptible crops are being grown too frequently.

The beet eelworm attacks and forms cysts on many crop and weed plants. Any small particle of soil containing cysts which is carried to clean land is capable of spreading the pest, so the means of dissemination are numerous.

All chemical means of control are costly and cropping rotations have to be designed so that the interval between susceptible crops allows the eelworm population to fall to levels at which serious injury does not occur. On the continent of Europe where the beet eelworm has been known since the end of last century, no trouble arises where long rotations are followed in which beet or other susceptible crops appear only once in six years. On heavy land beet eelworm populations build up slowly and the pest is less serious than on light land.

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(33) Clarke, W.C., "A Review of Plant Parasitic Nematodes in New Zealand", Sixteenth N.Z. Weed Control Conference, pp. 91-95, 1963.

(34) Clarke, W.C. Personal communication.

1ª.5.9 Harvesting Sugar Beet

In Britain the growers crop is purchased by the British Sugar Corporation at a specified price per ton of correctly topped and cleaned beet. For the 1963 crop the contract price, which is negotiated by the National Farmers' Union and the Government during the Annual Review of farm prices, will be based on a sixteen per cent sugar content with a price differential of 10/-, plus or minus, for each one per cent deviation in sugar content. The differential has been increased from 7/6 to encourage the production of beet of a higher sugar content, which reduces factory costs.

When the beets are ripe the outer leaves tend to fall down. Factory operations last for about three months so lifting commences before the crop if fully ripe or has attained its maximum sugar content. The last of the crop may undergo some shrinkage, especially if it has been clamped. In order to give growers equal advantages in time of delivery, dated delivery permits are allocated to each grower. Thus delivery is not the same as harvesting and, although it is best for lifting to keep pace with delivery, it is rarely possible to synchronize the two so that there is no beet in store on the farm. It is essential to keep lifting ahead of delivery and to be able to draw on roadside dumps of beet for delivery during inclement weather when lifting may be impossible. The soil type, acreage of beet, development of the crop, weather and delivery permits all control the length of the beet harvest. Lifting may carry on longer on the lighter soils than is possible on the clays from which beet should be removed early, even though this entails storage on the farm.

A complete sugar beet harvester should top the beet correctly (at the lowest leaf scar), lift the roots without injury, clean them and elevate them into a truck or trailer as well as keeping the tops sufficiently clean for stock feeding. The most efficient topping mechanisms are those which work on the beet while they are still in the ground.[35] The topping unit has a device which rides on the crowns of the beet and adjusts the topping knives for tall or short plants. Machines can be obtained, however, which top the beet after they have been lifted. Many harvesters lift the beet with conventional shares while others employ a rotary type lifting mechanism. Since a considerable quantity of soil adheres to the beet after lifting, a cleaning action is usually incorporated in the elevator mechanism. Some harvesters have a bulk tank either on the harvester itself or mounted on the tractor into which the beet is elevated, the load being dumped at the headland. The complete harvester can, in addition, elevate the tops into a trailer, windrow them or spread them for ploughing in. Harvesting can also be carried out in two stages by topping with one machine and following with another which lifts the previously topped beet.

Carting off the tops at the time of harvest makes the whole operation of transport a very big undertaking and could only be considered where plenty of men and machines were available.[36]

The leaves can be collected cleanly and directly by a forage harvester before the roots are harvested.[37] The crowns remain so a harvester fitted with a topping mechanism is used to lift the beet. This method eliminates top spoilage problems but the crowns are lost and less stock food is reclaimed. Lifting should follow leaf removal within two days to minimise sugar losses.

Dirt tares may be high if beet harvested in wet conditions are delivered straight to the factory. This difficulty can be overcome by clamping the beet and loading them through a cleaner loader on to road transport. Considerable care in clamping methods is necessary to keep storage losses to a minimum.

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(35) Watson and More, op. cit., p.182.

(36) Mawbry, M.E., "Silage from Sugar Beet Tops", Brit. S.B. Rev., 32(1): 27-29, 1963.

(37) Maynard, E.J., and Knaus, K.D., "Beets and Meat", 3rd Edition. The Great Western Sugar Company, Denver, Colorado, p.49.

Culpin[38] says that one of the chief remaining difficulties in beet harvesting is the amount of damage done to soil structure by the tractors and trailers used in harvesting and carting off the crop. With a single row harvester every inter-row space is first pressed down by the tractor and harvester and then by the tractor and trailer (or truck) running alongside. The result can be harmful to following crops if harvesting takes place in wet conditions.

Culpin also observes that preparation for mechanical harvesting, as for precision drilling and mechanical thinning, begins in autumn with level ploughing, drilling must be straight and the field must be laid out to facilitate the use of the harvester and to avoid unnecessary hand work at the row ends.

1'.5.10 Factory Requirements for Sugar Beet

The factory requires beet with a high sugar content which will produce a juice with a high purity.

During growth highly complex substances are produced besides sugar (sucrose) and the amount and type of these substances determine the quality of the juices in the roots. Impurities, especially certain nitrogenous compounds referred to as "noxious nitrogen" reduce the amount of sugar than can be extracted from the beet. This factor should be considered when making nitrogenous fertilizer recommendations so that excessive dressings are avoided. Plant population also affects purity. Within limits, every additional thousand plants per acre increases the purity of the crop by 0.3 per cent, probably because large beet often produce rough, coarse and large crowns.

A healthy crop is also necessary to ensure high-quality beet. Early establishment increases disease resistance and reduces the likelihood of a severe virus yellows attack. This disease has a highly adverse effect on juice purity.

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(38) Culpin, C., "Farm Mechanization Management", Crosby and Lockwood and Son, (London), 1959, p.182.

Beet are liable to damage by severe frost. The cell structure of the roots is destroyed but, as long as they remain frozen, they can be processed successfully. Thawing - especially rapid thawing - causes decomposition of the sugars and a viscous fermentation starts, resulting in the production of mucilaginous substances. These substances seriously interfere with the filtration of the treated juices. Care should, therefore, be taken to see that clamped beet are protected from severe frost.

Efficient extraction requires roots that will cut cleanly and produce high quality slices (cossettes). Bolters and under-topped beet give slices of poor quality. Early bolters are "woody", low in sugar, difficult to slice and quickly clog and damage the slicing machinery, while undertopped beet are much lower in sugar and purity than properly topped beet.

Stones and trash (leaves, stalks, straw, weeds) delivered with the beet also impair factory efficiency. Stones damage the slicing machinery and trash clogs it up, both causing delays which may slow down the rate at which beet can be received.

Dirt delivered with the beet is, however, the greatest problem. If the beet are clean the growers delivery costs are lower. Less labour is required for loading and the likelihood of deterioration in clamps on the farm and at the factory is reduced. When clean beet are delivered the loss of valuable top soil from the farm is minimised and the problems of soil and effluent disposal eased at the factory.

Efforts are now being made in Britain to improve both the sugar percentage and purity of beet. Both have fallen steadily over the last twenty years due to the emphasis on quantity rather than quality. The new basis of payment has been introduced to encourage this improvement. A large experimental programme is under way in an attempt to improve the purity of the juice so that more sugar can be extracted.[39] In Britain in the 1931-35 period it took approximately six tons of roots to produce one ton of sugar, while today (1961) it takes about eight tons.[40]

1°.5.11 Strains and Varieties

Sugar beet has been grown in continental Europe for much longer than in Britain. British strains of seed all owe much to Continental varieties from which they originated. They have, however, by now been adapted to English conditions. Continental strains are commonly classified into three groups:

(a) E types - strains producing large roots with relatively low sugar content.

(b) Z or ZZ types - strains producing fairly small roots with a high sugar content.

(c) N types - strains, intermediate in size of root and sugar content.

This classification in terms of sugar percentage is greatly overshadowed in Britain by differences due to soil, season or incidence of disease. The classification too, should not be confused with sugar yield for National Institute of Agricultural Botany trials have not shown any consistent difference between the calculated yield of sugar of the E and N types. This is because crops with low sugar content often give high yields of roots resulting in normal or high yields of sugar per acre.

A classification that does have some agricultural value is based on the amount of foliage developed by the plant. Using this character the strains may be divided into small, medium and large topped strains. Since the tops are

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(39) Carruthers, A.C., "Sugar Beet Quality for Processing", Brit. S.B. Rev., 31(3): 129-132, 1963, and

Campbell, G.K.G., "The New Beet Contract - Role of the Plant Breeder", Brit. S.B. Rev., 31(3): 135-137, 1963.

(40) Battle, G.F.N., "Fresh Fields to Conquer", Brit. S.B. Rev., 30(2): 87, 1961.

greatly influenced in their development by soil and climate and since they have considerable value as stock food the top character of a strain is often of great interest to a grower. The difference between strains is fairly constant in Britain, the large topped strains giving about 25 per cent more weight of tops than the smallest topped strains.

Detailed information concerning strains of sugar beet is obtained from comprehensive field trials conducted by the British Sugar Corporation and the National Institute of Agricultural Botany. These trials, together with tests of new strains, have been used to compile the list of recommended strains published by the Institute. Reports on the trials are published annually in the British Sugar Beet Review.(41) Wherever sugar beet is grown farmers have available to them data on the characteristics and performance of all strains and varieties likely to be sown.

1*.5.12 Transplanting Sugar Beet

Direct transplanting of sugar beet is not practicable owing to excessive root damage but recent work at Cambridge(42) has shown that transplanting in soil blocks is technically possible. Transplanting ensures that a stand of 30,000 evenly spaced plants, with no weeds in the immediate vicinity of the plants, can be secured. Thinning problems are eliminated and inter-row cultivation and mechanical harvesting simplified.

This work is still at the experimental stage and many problems in the manufacture of the blocks and the development of handling and transplanting equipment on the farm await solution.

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(41) Willey, L.A., "Trials of Commercial Varieties of Sugar Beet", Brit. S.B. Rev., 31(4): 177-181, 1963.

(42) Palmer, J., and Wilton, B., "Transplanting Sugar Beet Seedlings in Soil Blocks", Jnl. Ag. Enging. Res., 7(2): 141-149, 1962.

A P P E N D I X II

GROSS MARGINS

2'.1 : GROSS MARGINS - CASE FARM 1

Activity	Unit	Gross Revenue (£)	Variable Costs (£)	Gross Margin (£)
Wheat (P_1)	1 acre	37.25	12.01	25.24
Sugar Beet (P_2)	1 acre	75.00	31.41	43.59
Swedes (P_3)	1 acre	-	3.00	-3.00
Hay (P_4)	1 acre	-	6.34	-6.34
Arable Grazing (P_5)	1 acre	-	0.94	-0.94
Non-Arable Grazing (P_6)	1 acre	-	0.94	-0.94
Sheep (P_7)	10 E.E's	41.30	3.30	38.00
Cattle (P_8)	1 cow	18.30	4.20	14.10
New Grass	1 acre	-	5.28	-5.28

Note: New grass has not been included as an activity.

2'.2 : GROSS MARGINS - CASE FARM 2

Activity	Unit	Gross Revenue (£)	Variable Costs (£)	Gross Margin (£)
Wheat (P_1)	1 acre	42.00	10.25	31.75
Barley (P_2)	1 acre	38.25	9.43	28.82
Barley and Greenfeed (P_3)	1 acre	38.25	11.83	26.42
Sugar Beet (P_4)	1 acre	87.50	38.99	48.51
Swedes (P_5)	1 acre	-	3.56	-3.56
Hay (P_6)	1 acre	-	6.34	-6.34
Grazing (P_7)	1 acre	-	1.52	-1.52
Sheep (P_8)	10 E.E's	44.00	9.75	34.25
Wethers (P_9)	10 wethers	16.70	4.20	12.50
Cattle (P_{10})	1 steer	35.00	23.00	12.00
New Grass	1 acre	-	6.26	-6.26

Notes: 1. New grass has not been included as an activity.

2. A loss of 5/- per head has been assumed on the sale of the wethers as purchase and sale prices can fluctuate widely.

2'.3 : DETAILS OF ROTATIONS USED IN SECTION 7.8

Rotation Number	Units (Acres)	Crops Included in the Rotation	Gross Margin (£)
1	1	O.G. — W_1 — N.G.	-6.26
2	1	O.G. — Sw — N.G.	-9.82
3	1	O.G. — S.B. — N.G.	-6.26
4	1	O.G. — W_1 — G.F. — N.G.	-8.66
5	2	O.G. — W_1 — G.F. — W_2 — N.G.	-8.66
6	2	O.G. — W_1 — W_2 — N.G.	-6.26
7	2	O.G. — W_1 — G.F. — Sw — N.G.	-12.22
8	2	O.G. — Sw — W_1 — N.G.	-9.82
9	2	O.G. — W_1 — S.B. — N.G.	-6.26
10	2	O.G. — S.B. — Sw — N.G.	-9.82
11	2	O.G. — S.B. — W_1 — G.F. — N.G.	-8.66
12	3	O.G. — W_1 — G.F. — Sw — W_2 — N.G.	-12.22
13	3	O.G. — W_1 — Sw — W_2 — N.G.	-9.82
14	3	O.G. — W_1 — S.B. — W_2 — N.G.	-6.26
15	3	O.G. — S.B. — Sw — W_1 — N.G.	-9.82
16	3	O.G. — S.B. — W_1 — G.F. — W_2 — N.G.	-8.66
17	3	O.G. — W_1 — S.B. — Sw — N.G.	-9.82
18	3	O.G. — S.B. — Sw — W_1 — G.F. — N.G.	-12.22
19	4	O.G. — W_1 — G.F. — Sw — S.B. — W_2 — N.G.	-12.22
20	4	O.G. — W_1 — Sw — S.B. — W_2 — N.G.	-9.82

Notation: O.G. - old grass
N.G. - new grass
W_1 - first year wheat
W_2 - second year wheat
Sw - swedes
S.B. - sugar beet
G.F. - greenfeed barley

Note: 1. Where a rotation occupies land for a fractional part of its last year, an allowance has been made in the model for the pasture feed supplied by the rotation in that last year.

2. The gross margins of wheat and sugar beet have been excluded from the rotation gross margin.

2'.4 : GROSS MARGINS - CASE FARM 3

Activity	Unit	Gross Revenue (£)	Variable Costs (£)	Gross Margin (£)
Potatoes (P_1)	1 acre	240.00	122.52	117.48
Potatoes and Greenfeed (P_2)	1 acre	240.00	124.73	115.27
Wheat (P_3)	1 acre	49.00	12.10	36.90
Sugar Beet (P_4)	1 acre	100.00	26.05	73.95
Choumoellier (P_5, P_6)	1 acre	-	4.64	-4.64
Mangolds (P_7)	1 acre	-	5.29	-5.29
Swedes (P_8)	1 acre	-	4.55	-4.55
Arable Grazing (P_9)	1 acre	-	-	0.00
Non-arable Grazing (P_{10})	1 acre	-	1.50	-1.50
Lucerne Hay (P_{11}, P_{12}, P_{13})	1 acre	-	13.87	-13.87
Dairy (P_{14})	10 E.E's	81.49	5.85	75.64
Wethers (P_{15})	10 wethers	16.70	4.20	12.50
New Grass	1 acre	-	8.90	-8.90

Notes: 1. No topdressing is applied to permanent pasture on the home farm.

2. New grass has not been included as an activity.

A P P E N D I X III

BASIC MATRICES

The basic matrices for the three case farms are presented in this Appendix.

3'.1 INTERPRETATION

Consider the matrix for Case Farm 1 in section 3'.3.

The gross margins and resource availabilities are clearly shown. The figures in the body of the table are the technical coefficients. A positive figure shows that the activity consumes, or uses, a resource, while a negative coefficient indicates that the activity contributes to the supply of a resource. Taking the activity P_2, we see that one acre of sugar beet does not require labour in January, February or March but requires 3.34 hours of April labour, 3.44 hours of May labour, ..., and 0.83 hours of December labour. The activity takes up 1.0 acre of the maximum sugar beet acreage, 1.0 acre of arable land, contributes 5.0 units of May-August feed and 2.0 units September-December feed. Similar interpretations apply to the other activities.

3'.2 THE COMPUTER

The computations were carried out on the I.B.M. 1620 Data Processing equipment installed in the Mobil Computer Laboratory of the Engineering School, University of Canterbury.

The programme used was the Linear Programming Routine, I.B.M. programme library number 10.1.002.

3°.3 : CASE FARM 1

Gross Margins (£)			25.24	43.59	-3.00	-6.34	-0.94	-0.94	38.00	14.10
Constraints	Resource Availability	Relationship	Wheat (1 ac.) P_1	Sugar Beet (1 ac.) P_2	Swedes (1 ac.) P_3	Hay (1 ac.) P_4	Arable Grazing (1 ac.) P_5	Non-Ar. Grazing (1 ac.) P_6	Sheep (10 E.E's) P_7	Cattle (1 Cow) P_8
Monthly Labour:										
1. January	570 hours	≥			1.27	1.93			0.37	0.32
2. February	570 "	≥	0.37						0.76	
3. March	570 "	≥				0.28	0.28	0.28	0.37	
4. April	570 "	≥		3.34					0.37	
5. May	570 "	≥	1.16	3.44	1.16				0.37	
6. June	570 "	≥		3.44					0.46	0.60
7. July	570 "	≥	0.58	0.48					0.46	0.60
8. August	570 "	≥	0.58	0.29	0.58				0.76	0.94
9. September	570 "	≥	0.80	1.79	0.58				1.05	
10. October	570 "	≥		2.14	0.80				2.70	
11. November	570 "	≥		1.56					0.55	
12. December	570 "	≥		0.83					0.37	
13. Max. Sugar Beet	60 acres	≥		1.0						
14. Max. Wheat	80 "	≥	1.0							
15. Max. Cash Crop	125 "	≥	1.0	1.0						
16. Arable Land	250 "	≥	1.0	1.0	1.0	1.0	1.0			
17. Non-arable Land	250 "	≥						1.0		
18. May-Aug. Feed	0 E.E's	≥		-5.0	-40.0	-9.5	-2.0	-1.5	10.0	6.0
19. Sept.-Dec. Feed	0 "	≥				-2.0	-7.0	-5.0	10.0	6.0
20. Jan.-April Feed	0 "	≥		-2.0		-2.0	-5.0	-3.0	10.0	6.0
21. Hay	0 tons	≥				-1.5			0.15	0.5

3'.4 : CASE FARM 2

Gross Margins (£)			31.75	28.82	26.42	48.51	-3.56	-6.34	-1.52	34.25	12.50	12.00
Constraints	Resource Availability	Relationship	Wheat (1 ac.) P_1	Barley (1 ac.) P_2	Barley and G.F. (1 ac.) P_3	Sugar Beet (1 ac.) P_4	Swedes (1 ac.) P_5	Hay (1 ac.) P_6	Grazing (1 ac.) P_7	Sheep (10 E.E's) P_8	Wethers (10 weth.) P_9	Cattle (1 rising 2yr. st.) P_{10}
Monthly Labour:												
1. January	570 hours	≥					0.58	1.93		0.10	0.02	
2. February	570 "	≥								0.10	0.02	
3. March	570 "	≥	0.37	1.17	3.22			0.28	0.28	0.25	0.17	
4. April	570 "	≥				3.34				0.10	0.02	
5. May	570 "	≥				3.44				0.24	0.17	
6. June	570 "	≥				3.44				0.80	0.64	0.25
7. July	570 "	≥				0.48				0.49	0.35	0.50
8. August	570 "	≥	1.98			0.29				0.95	0.34	0.50
9. September	570 "	≥	1.29			1.79				2.32	0.02	
10. October	570 "	≥		3.50	3.50	3.14	1.98			0.76	0.02	
11. November	570 "	≥	0.15	0.15	0.15	1.16	1.98			0.61	0.30	
12. December	570 "	≥				0.83	0.58			0.20	0.13	
13. Land	350 acres	≥	1.0	1.0	1.0	1.0	1.0	1.0	1.0			
14. Max. Cereal	120 "	≥	1.0	1.0	1.0							
15. Max. Barley	25 "	≥		1.0	1.0							
16. Max. Sugar Beet	85 "	≥				1.0						
17. Max. Cash Crop	175 "	≥	1.0	1.0	1.0	1.0						
18. May-Aug. Feed	0 E.E's	≥			-6.0	-7.0	-45.0	-10.0	-2.5	10.0	7.5	4.0
19. Sept.-Dec. Feed	0 "	≥			-4.0			-2.0	-8.0	10.0	5.0	3.0
20. Jan.-April Feed	0 "	≥				-2.5		-2.0	-5.0	10.0	10.0	6.0
21. Hay	0 tons	≥						-1.5		0.15	0.09	0.45

3°.5 : CASE FARM 3

Constraints	Resource Availability	Relationship	Potatoes (1 ac.) P_1	Potatoes and G.F. (1 ac.) P_2	Wheat (1 ac.) P_3	Sugar Beet (1 ac.) P_4	Winter Chou. (1 ac.) P_5	Autumn Chou. (1 ac.) P_6	Mangolds (1 ac.) P_7	Swedes (1 ac.) P_8	Arable Grazing (1 ac.) P_9	Non-Ar. Grazing (1 ac.) P_{10}	Winter Lucerne (1 ac.) P_{11}	Spring Lucerne (1 ac.) P_{12}	Autumn Lucerne (1 ac.) P_{13}	Dairy (10 E.E's) P_{14}	Wethers (10 weth.) P_{15}
Gross Margins (£)			117.48	115.27	36.90	73.95	-4.64	-4.64	-5.29	-4.55	0.00	-1.50	-13.87	-13.87	-13.87	75.64	12.5
Monthly Labour:																	
1. January	670 hours	⩾								0.59			1.74	1.74	1.74	5.08	0.02
2. February	670 "	⩾														5.08	0.02
3. March	670 "	⩾			0.37							0.28				5.08	0.17
4. April	936 "	⩾	84.50	85.68		4.74							1.74	1.74	1.74	8.13	0.02
5. May	800 "	⩾	0.50	0.50		4.84										8.13	0.17
6. June	670 "	⩾	0.50	0.50		4.84										4.07	0.64
7. July	670 "	⩾	0.50	0.50		0.48				1.21						4.07	0.35
8. August	670 "	⩾	2.37	2.37	1.98	0.29	1.21	1.21					0.30	0.30	0.30	6.71	0.34
9. September	670 "	⩾	7.36	7.36	1.29	1.79	0.77	0.77	2.37	0.39						7.13	0.02
10. October	670 "	⩾	0.58	0.58		3.14	1.07	1.07	1.90	0.39			1.74	1.74	1.74	5.59	0.02
11. November	670 "	⩾			0.15	1.16	1.66	1.66	3.05	2.28						5.59	0.30
12. December	670 "	⩾				0.83			0.83	2.25			1.74	1.74	1.74	5.08	0.13
13. Max. Sugar Beet	26 acres	⩾				1.0											
14. Max. Potatoes	4 "	⩾	1.0	1.0													
15. Max. Wheat	43 "	⩾			1.0												
16. Max. Lucerne	5 "	⩾											1.0	1.0	1.0		
17. Arable Land	130 "	⩾	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0		
18. Non-arable Land	30 "	⩾										1.0					
19. Grazing	0 "	⩾									-1.0	-1.0				1.67	0.83
20. May-Aug. Feed	0 E.E's	⩾		-7.5		-10.8	-72.0			-50.0	-2.5	-1.5	-40.0			10.0	7.5
21. Sept.-Dec. Feed	0 "	⩾		-2.5					-80.0		-8.0	-5.0		-40.0		10.0	5.0
22. Jan.-April Feed	0 "	⩾				-3.6		-60.0			-5.0	-2.5			-40.0	10.0	10.0

__Note:__ In section 7.10.5, solutions C and D, the pasture output coefficients of P_9 and P_{10} were reduced to:

	P_9	P_{10}
(May-August Feed	-2.0	-1.0
(September-December Feed	-7.0	-3.5
(January-April Feed	-4.5	-2.0

A P P E N D I X IV

PRESENT AND FUTURE SUGAR POLICY IN NEW ZEALAND

A brief review of present sugar policy in New Zealand and the main points that should be considered in formulating future policies are presented in this Appendix.

4'.1 NEW ZEALAND'S PRESENT SUGAR POLICY

Practically all of New Zealand's sugar is imported in the form of raw cane sugar, which is refined in Auckland by the New Zealand Sugar Company[1].

Sugar imports into New Zealand are subject to import licensing except for imports of unrefined sugar of under 22 Dutch colour standard. Import duties of 1¼d per pound on refined sugar and 1d per pound on raw sugar have been levied since 1933. Raw sugar imported for refining enters free of duty under bond, an excise duty of 1d per pound being levied on the refined product.

The Government determines the methods of purchase and the terms of contracts under which the New Zealand Sugar Company obtains its supplies of raw sugar. Under the control of Prices Act 1947, the price of sugar is controlled by the Price Tribunal. After the purchase of raw sugar at a price related to the London daily price all the intervening stages of the production, distribution and sale of refined sugar are subject to price control.

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(1) The New Zealand Sugar Company is a wholly owned subsidiary of the Colonial Sugar Refining Company of Australia.

The main origins of imports are Australia and Fiji, which in most years since 1951 have supplied the bulk of New Zealand's requirements. Imports under the arrangements with the members of the Commonwealth Sugar Agreement have been made exclusively from Australia and Fiji because of their proximity to New Zealand. Table 4'.1 shows the origin of imports of raw sugar, in value terms, since 1953.

TABLE 4'.1

ORIGIN OF IMPORTS OF RAW SUGAR
(£000)

Year	Australia	Fiji	Taiwan	Cuba	Peru	Indonesia	Dominican Republic	Total
1953	1,723	1,174	252	-	-	-	-	3,149
1954	2,417	1,606	-	99	220	-	-	4,342
1955	2,567	1,454	-	-	-	-	-	4,021
1956	2,300	1,273	-	-	-	-	-	3,573
1957	2,880	1,239	-	-	-	143	-	4,262
1958	2,654	910	-	-	-	-	-	3,564
1959	1,897	884	-	-	-	-	-	2,781
1960	2,160	358	-	-	-	-	244	2,762
1961	1,529	531	-	-	-	-	995	3,055
1962	1,773	1,285	-	-	-	-	-	3,058
1963	5,229	-	336	-	457	-	967	6,989

Source: New Zealand Official Year Books for the years 1953-61 and the Department of Industries and Commerce for the years 1962-63.

The Commonwealth Sugar Agreement (C.S.A.) was first signed in 1951 for an eight year period. The Agreement is designed to develop the production of sugar in Commonwealth countries and to assist orderly marketing of sugar by providing long-term price stability based on "fair average costs of production". In each year since 1952 it has been progressively extended for a further year, the current expiry date being 1971. The Agreement provides for the marketing in Commonwealth importing countries of up to 2,175,000 tons of sugar per year. The parties to the

Agreement at present are the United Kingdom Government and representatives of the sugar industries and exporters in Australia, the West Indies and British Guiana, British Honduras, Mauritius, Fiji and East Africa (Tanganyika, Kenya and Uganda).

New Zealand has never been a member of the C.S.A. but in 1951 entered into an arrangement with the United Kingdom to purchase at the C.S.A. negotiated price all its raw sugar requirements for the years 1951 and 1952 and 75,000 tons annually until 1958. This worked to New Zealand's advantage initially as the landed cost of C.S.A. sugar was lower than that of raw sugar purchased at the world free market price. (See Table 4'.3) Surplus stocks subsequently depressed the free market price and by mid-1956 the C.S.A. price was £12 per ton higher than the world price. In 1956 agreement was reached with the United Kingdom and Commonwealth producers to release New Zealand from its obligation to take 75,000 tons of sugar at the negotiated price. The terms of the new arrangement were:[2]

(a) New Zealand was released from the obligation to purchase at the Commonwealth negotiated price as from 1 January 1957 - two years earlier than the actual expiry date.

(b) New Zealand undertook to purchase 75,000 tons of Commonwealth sugar annually for seven years (1957-63) but on a new price basis.

(c) The new price basis was called the "Commonwealth free market price". On this basis the price of sugar to New Zealand is the f.o.b. Queensland-Fiji (or other Commonwealth territory) equivalent of the current value at the time of purchase of "Commonwealth free market" sugar c.i.f. United Kingdom. The effect of this is that sellers receive the same f.o.b. return as on the world free market including the U.K. tariff preference of £3.15.-. per ton and New Zealand pays the "Commonwealth free market price" c.i.f., United Kingdom including the preference, less the freight London-Queensland or

(2) N.Z. Department of Industries and Commerce, Annual Report, 1958, p.57.

London-Fiji plus the freight Queensland or Fiji-New Zealand. In simpler language this means that New Zealand pays the London free market price plus £3.15.-. per ton less the freight to London plus the freight to New Zealand, freight charged from the point of production. This arrangement has been extended for a further year, to 30 December 1964.

New Zealand, except during the months of the Suez crisis and most of 1963 benefited from purchasing at prices related to the London free market price. The net saving has been estimated at £3 million to the end of 1963.(3) New Zealand purchases the balance of her requirements of approximately 50,000 tons at world prices without restriction as to source of supply.

4'.2 NEW ZEALAND'S FUTURE SUGAR POLICY

The New Zealand Government must decide which of three policies it will pursue. Firstly whether to continue to purchase sugar at or related to the world free market price, secondly whether to enter into long term contracts for the supply of part or all of her raw sugar needs and, thirdly, whether or not to encourage the establishment of a domestic beet sugar industry.

4'.2.1 Imports of Raw Cane Sugar

The average price of raw sugar on the free market was lower in most years since 1956 than prices under the United States Sugar Act or the Commonwealth Sugar Agreement. Both the United States and British sugar consumers have been subsidising producers who supply them under these agreements. The agreements do provide a stable price and market for sugar shipped under them but they have

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(3) Statement by the Minister of Industries and Commerce, Christchurch Press, 29 January 1964. The benefits would have been increased by up to £3.15.-. per ton (depending on freight charges) if the 75,000 tons per year had been purchased at world prices.

reduced the size of the free market as a proportion of world sugar production and trade thus creating conditions for violent price fluctuations as both political tensions and production levels change.(4)

Because of the tendency for price to fall after any deviation from an equilibrium position it seems likely that the average price of sugar over a number of years will be lower if New Zealand's requirements are purchased at the world free market price.(5) There would inevitably be fluctuations in the New Zealand retail price of sugar and sugar containing goods unless some form of equalising scheme was instituted. The guaranteed over-draft scheme at present operating between the Bank of New Zealand and the New Zealand Sugar Company is one such arrangement. To avoid over-draft finance it would be necessary to build up a substantial fund, say £5 million, by keeping the retail price of sugar at a higher level than the world price when the world price was low.(6)

4'.2.2 A Domestic Sugar Beet Industry

The question of a domestic sugar beet industry raises many problems many of which cannot be solved with the knowledge and data at present available. It is true to say, however, that beet sugar production is protected or subsidised in all countries where it is grown. (Cane sugar production is subsidised in the

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(4) Frampton, A.R., "The International Sugar Situation and New Zealand's Sugar Policy", Publication No. 4, Agricultural Economics Research Unit, Lincoln College, 75 p.

(5) Snape has analysed the past price behaviour of sugar on the world market. He concludes that a cob-web effect operates in sugar production with a tendency for a decline in average price as the cycle proceeds. There appears to be an inherent tendency for any price fluctuation (whether upward or downward) on the free market to bring an increasing average supply and a declining average price. See:

Snape, R.H., "Protection and Stabilization in the World Sugar Industry", Unpublished Ph.D. Thesis, University of London, June 1962, pp. 84-126, and Frampton, A.R., <u>op. cit.</u>, pp. 17-18 and pp. 50-53.

(6) A number of different equalising schemes could be proposed but a discussion of them is not relevant to this study.

United States and cane sugar producers who export a proportion of their output to the United States or the United Kingdom receive, in most years, prices that are higher than the world price.(7)

An attempt is now made to relate the price of £5 per ton for sugar beet to the world price of raw sugar. At the retail price ruling in February-March 1963 (£75 per ton) Mr Campbell-MacDonald said that beet sugar could compete with imported raw sugar provided the one penny per pound excise duty was waived on domestically produced beet sugar. This is equivalent to protection of £9.6.8 per ton. Now, assuming that beet sugar could be retailed at £75 per ton in the absence of the excise duty, its competitive price in February-March 1963 would have been £84.6.8 (£75.-.-. plus £9.6.8), say, £84 per ton. That is, at £84 per ton for refined beet sugar the factory could pay the producer £5 per ton for clean, topped beet.

The cost (including excise duty) of refining and selling sugar in New Zealand has been 4.3d per pound, or approximately £40 per ton, for the last decade.(8) If we take this figure of £40 per ton as an estimate of the cost of refining and selling beet sugar in New Zealand the factory could afford to pay £44 (£84 less £40) or less, for raw sugar.

Now the tonnage of beet purchased by the British Sugar Corporation and the resultant production of white sugar is given in Table 4'.2 for the years 1960-63. This shows that an average of 7.7 tons of beet were required to produce one ton of white sugar or 1.09 tons of raw sugar. If we assume that a New Zealand factory would operate with this efficiency then the cost of the raw sugar in the beet would be £35.3 per ton. This leaves a margin of £8.7 (£44 less £35.3) for

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(7) Snape, R.H., "Some Effects of Protection in the World Sugar Industry", Economica, February 1963, p.66.

(8) "The World Sugar Economy, Structure and Policies", Vol. I, International Sugar Council, London, 1963, Table 3, p.311.

extracting raw sugar after credit has been given for sales of sugar beet pulp.[9] Since the extraction and refining of beet sugar would be a continuous process, the refining margin may be over-estimated and the extraction margin under-estimated.

TABLE 4'.2

PRODUCTION OF WHITE SUGAR FROM BEET

Year ended 31 March	Beets Bought (tons)	Sugar in Terms of White Sugar (tons)
1960	5,509,769	773,292
1961	7,215,261	887,525
1962	5,936,479	760,388
1963	5,313,003	686,512
Totals	23,974,512 (a)	3,107,717 (b)

Notes: The average tonnage of beet required to produce one ton of refined sugar during 1960-63 = $\frac{a}{b}$ = 7.7 tons.

Using a conversion rate of 92 parts refined = 100 parts raw 7.7 tons of beet produce 1.09 tons of raw sugar.

At £5 per ton for New Zealand beet the cost of the raw sugar in the beet is £35.3 per ton.

Source: Report of the Directors and Statement of Accounts for the year ended 31 March 1963, British Sugar Corporation Ltd., London, p.18.

However, when the figure of £44 per ton for raw sugar (from beet) is assumed it can be seen from Table 4'.3 that the world price of raw sugar has been

(9) Comparable sugar extraction margins of £7.3 and £6.5 per ton for the years 1961-62 and 1962-63 can be deduced from the accounts of the British Sugar Corporation. The refining margin approximates 1d per pound compared with a New Zealand margin of 2.2d per pound. Since these British costs are averages from 14 factories and 4 refineries of various capacities they may be misleading when applied to a single factory in South Otago.

See: "Report of the Directors and Statement of Accounts for the year ended 31 March 1963", British Sugar Corporation, London, pp. 7-8.

above this in only 1951, 1952, 1957 and 1963, since 1950. Thus a domestic beet sugar industry would have needed protection in some form during this period to have maintained a payout of £5 per ton to farmers. In the years 1953, 1954, 1955, 1958, 1959, 1960, 1961 and 1962, protection additional to the remission of the excise duty would have been required.

TABLE 4'.3

THE C.S.A. NEGOTIATED PRICE AND THE WORLD PRICE OF RAW SUGAR 1950-1964

Year	Average World Price[a] (£/ton)	C.S.A. Price[b] (£/ton)
1950	40. 16. 8	30. 10. 0
1951	49. 11. 8	32. 17. 6
1952	45. 13. 4	38. 10. 0
1953	30. 18. 4	42. 6. 8
1954	29. 15. 0	41. 0. 0
1955	31. 10. 0	40. 15. 0
1956	35. 0. 0	40. 15. 0
1957	46. 17. 6	42. 3. 4
1958	31. 7. 6	43. 16. 8
1959	27. 5. 0	45. 2. 0
1960	28. 6. 0	44. 8. 10
1961	25. 13. 0	45. 2. 0
1962	25. 19. 0	45. 15. 3
1963	71. 14. 0	46. 0. 10
1964	- - -	46. 0. 10

(a) c.i.f. U.K., ex-duty.

(b) Sellers are liable for agreed rates of freight and insurance and buyers for any additional charges.

Source: Frampton, A.R., op. cit., Table 17, p.73.

It should also be noted that if the excise duty of 1d per pound was not remitted, then the beet sugar industry could afford to pay only £35 per ton, or less, for raw sugar if it was to compete with cane sugar retailing at £75 per ton. Under these conditions the return to the farmer could not exceed £3.7 per ton of topped beet. To compete with the lowest annual average world price for raw cane sugar shown in Table 4'.3 the price to the farmer would fall to £2.4 per ton.

The above discussion would, of course, be greatly strengthened if the costs of beet sugar extraction and refining could have been presented with confidence. The author has, in the course of a comprehensive review of the literature on sugar beet production, not discovered satisfactory figures which could be used to replace the estimates inferred from Mr Campbell-MacDonald's assessment of the prospects for sugar beet in South Otago.

4'.3 SUMMARY

It has been shown, using tentative estimates, that a sugar beet industry would have needed protection in most years since 1950 to enable a payout of £5 per ton of beet to be maintained to farmers. This indicates that careful and thorough research should be conducted into the industry costs and benefits before the construction of a factory is commenced.(10)

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(10) The author has attempted a tentative evaluation of the worthwhileness of the sugar beet industry, which suggests that a substantial premium may need to be placed on foreign exchange earnings if the establishment of the industry is to be justified.
See: Frampton, A.R., <u>op. cit.</u>, pp. 32-39.

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