

A STATIC MODEL OF ECONOMIC EFFICIENCY IN VEGETABLE
PRODUCTION IN MANITOBA: AN APPLICATION OF
LINEAR PROGRAMMING

A Thesis

Presented to

the Faculty of Graduate Studies and Research

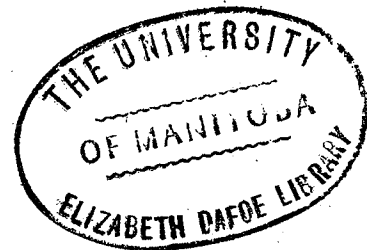
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CHAPTER I

INTRODUCTION

I. THE MANITOBA VEGETABLE INDUSTRY

Vegetable production, as a component of the agricultural economy of Manitoba, has largely been subordinated by the emphasis placed upon wheat and other cereal crops. The wheat economy of the province has been stressed in the constant drive to maintain the competitive position of Manitoba in the international market. The vegetable industry, however, has not enjoyed comparable promotion and development, and prior to the Second World War, production was limited to that required for local consumption. During this earlier period, large quantities of vegetables were imported because of the high degree of seasonality of production and the lack of adequate storage technology.

Nevertheless, pockets of vegetable production developed around the large urban centres of consumption--mainly the Winnipeg area. Domestic supply remained highly seasonal, particularly with respect to the more perishable vegetables such as tomatoes and celery, and the off-season was characterized by an inflow of fresh produce from the southern United States. In some cases imports competed successfully even when domestic supplies were available since local vegetables were comparatively lower in quality. In spite of brisk competition and irregularities in supply, however, the Winnipeg-centred

vegetable industry gradually expanded and developed attendant wholesale and retail marketing institutions.

Meanwhile agricultural researchers assembled and disseminated technical information on varieties and production techniques suitable to Manitoba conditions, allowing local producers to compete successfully with imports. Improved storage techniques extended the time span over which locally grown vegetables were available to the consumer.

In the early 1950's the trade began to seriously consider the possibility of export operations. Producers were now in a position to produce a surplus over local requirements and the marketing institutions had developed the ability to channel it into the export market. Manitoba vegetables began moving into Saskatchewan, Alberta, Ontario and the United States on a modest scale. The bulk of this technological and market progress in the vegetable industry has taken place at an increasing rate over the past twenty years.

Recently, the development of Manitoba's vegetable industry has proceeded at an accelerated rate with the introduction of processing plants into the province. This has opened a new market for producers who are becoming increasingly aware of the importance of efficiency at both the production and marketing levels. This is illustrated by the formation in 1953 of the Vegetable Growers Association of Manitoba (V.G.A.M.) and of the Manitoba Vegetable Marketing Commission in 1965. The V.G.A.M. was organized in an

attempt to collectively attack problems of production, promotion, quality control, and marketing. The Vegetable Marketing Commission was formed under provincial legislation to control, regulate, and market all vegetables produced in Manitoba on behalf of the producer. Although supported by the larger commercial growers, this compulsory marketing board was rejected in a referendum held in 1967.

Small producers, large in number but collectively responsible for a relatively small proportion of total output, are slowly disappearing as the trend toward larger and fewer production units continues. Only the larger units are efficient enough to keep abreast of the rapid technological change and brisk competition for markets. These growers have demonstrated the desire to organize their efforts to promote stability and efficiency in the industry and to exploit potential out-of-province markets. Future development of the Manitoba vegetable industry is dependent upon continued efforts toward greater efficiency in production and marketing.

II. NATURE OF THE PROBLEM

The problem investigated in this study may be stated as: how to organize a vegetable production unit in order to achieve the highest possible net income. This optimization must be achieved within a dynamic industry which is characterized by a shortage of qualified labor at moderate wage rates, coupled with difficulties in mechanizing and dispersion of production from the large urban centres

of consumption. These specific problems associated with the vegetable industry bear further explanation.

Rising property taxes and land values in proximity to urban centres of consumption (especially Winnipeg) have induced many vegetable growers to move their location of production to other areas. This has resulted in new cost structures, compounding the difficulties posed by the need to adjust to a changing industry.

Further reorganization is necessitated by the rising cost of labor. Production of vegetable crops requires labor which is relatively high in skill and experience so that the various tasks involved can be handled with preciseness and dispatch. Reliable labor of this caliber, at a price which most vegetable growers feel they can pay, is in short supply. Indications are that casual Indian labor can be obtained at a reasonable rate if adequate temporary living accommodations are provided by the grower. There still remains the question of how the available labor can be most efficiently utilized.

Mechanization is proceeding gradually, though hindered by the high capital investment required and technical difficulties arising from the delicate nature of many vegetable crops.

Thus, the conditions under which the farm firm must operate are changing. These external factors are reflected within the firm by variation in cost structures, production techniques, and resource supplies available.

The success of a farm business depends on its ability to adjust to changing conditions. Income level is dependent upon how well a firm organizes its resources and production capabilities under a given set of conditions. When these conditions change, the firm must move to reorganize its operations so that income will remain at (or move to) the level which represents the optimum for that firm. Therefore, the problem with which this study deals is one of efficiency in resource allocation and enterprise combination. This report deals with this question in the context of the conditions presently faced by the commercial vegetable producers of Manitoba.

CHAPTER II

SCOPE AND METHOD

This research report is the result of a study initiated by the developing complexities of the Manitoba vegetable industry, as outlined in the previous chapter. The rapid development of the industry has led to the need for research into the economics of vegetable production. The present study is an initial stage of what is hoped will be a continuing inquiry into the economic aspects of vegetable production.

The problem stated, it is now appropriate to define the objectives, propose hypotheses, and discuss the method of analysis used to attain the objectives and verify or refute the hypotheses.

I. OBJECTIVES

This study is aimed at providing a solution to the planning problems which face commercial vegetable growers. The present characteristics of the vegetable industry have led to a greater need for information in the area of resource allocation and enterprise combination. The over-all objective of this study is to determine the combination of enterprises (and hence, resources) which will maximize the income of the Manitoba vegetable producer under specified conditions.

In view of the fact that vegetable farms in Manitoba are a

very diverse group, a more detailed enumeration of the specific objectives follows.

A substantial portion of the study is devoted to a case farm which is an established vegetable farm exhibiting a relatively large capital input. The objectives pertaining to this portion of the study are:

1. determination of the optimum combination of enterprises which is permitted by the set of resources present on the case farm in 1967;
2. to obtain an indication of the desirable course of expansion of the farm business when the above complement of resources is allowed to increase in magnitude and change in composition;
3. exploration of the possibility of introducing a feeder cattle enterprise into the farm business with a view to utilization of culled vegetables; and
4. determination of the effect of feeder cattle on the optima obtained in (1) and (2).

The remainder of the study is devoted to generalization of the case model so that similar objectives, which are applicable to commercial vegetable growers at large, may be attained.

Specifically:

5. to compute optimum solutions for a broad range of resource levels in order to approximate other farm

businesses in Manitoba whose area of specialization is vegetable crops, yet whose complement of resources and access to resources differ from the case farm.

A more detailed explanation of how these objectives are attained follows in Chapter III.

II. DESIGNATION OF HYPOTHESES

An hypothesis is a "proposition not known to be definitely true or false, examined for the sake of determining the consequences which would follow from its truth" [2, p. 384]. Hypotheses are formed as the analysis proceeds and are the products of the known facts and the intuition and experience of the researcher. Their purpose is to guide the search for a solution.

During the initial stages of the analysis, the following hypotheses were suggested by the relevant facts and stated objectives:

1. because of the labor-intensive nature of vegetable crops, the labor resource will play an important restrictive role in determining the optimum combination of enterprises;
2. feeder cattle enterprises will not play a significant role in the optimum plan because of their inability to compete with vegetable crops for

investment capital; and

3. a feeder cattle enterprise will be included in the optimum production plan only during that period of the year when operating capital is not required for the vegetable cropping enterprises.

III. CHOICE OF AN EMPIRICAL TOOL

Having defined the problem, laid out the objectives, and suggested hypotheses, it is necessary to choose a method of analysis which most effectively promotes the attainment of the objectives. The empirical tool must be chosen with reference to the structure of the functional unit which is to be simulated.

The Firm and its Management

The firm or "business", as defined by Wheeler [24, pp. 25,26] is "an institution organized and operated to provide goods and services to society under the incentive of private gain . . . (it) uses resources for the accomplishment of (these) objectives".

The classical concept of "private gain" is that of monetary profit, though other incentives such as growth, prestige, service, and public acceptance are now considered as often being important to the firm [24]. The model in this study uses as the incentive, or objective, net income, truncated by market limitations and subjective preferences which reflect hedging against risk and the desire for stable growth.

Decision-making in any business organization is the sole responsibility of management. This "human activity which directs and controls the organization and operation of a business enterprise" [24, p. 200] is accountable for the success of the firm in reaching its objectives. The function of management is broken into five tasks [4, p. 7]:

1. getting of ideas and making observations,
2. analysis of observations, including formulation and reformulation of problems and ideas concerning their solution,
3. decision-making,
4. action, and
5. acceptance of responsibility for the action.

Management can not make a decision about future production without incurring a risk, for the future is never known with certainty. This is particularly the case when technology and market structure are as complex as those characterizing the modern vegetable industry. The farm manager can, however, make use of the tools at his disposal to minimize the risk associated with production planning.

This report deals mainly with the second task of management. The technique of linear programming is used as an aid in the analysis of the problem and search for a solution. The final decision remains the responsibility of management.

The following brief examination of the technique of budgeting will assist in the explanation of the utility of linear programming as a tool of management.

Budgeting

The budget is a rigorous procedure for planning farm operations. The objective of budgeting is "to compare alternative plans for the use and combination of farm and non-farm resources for prospective profit" [11, p. 357]. The budget, as an analytical tool, consists of preparing a summary of receipts and expenses showing net farm income of the proposed plan, and a comparable summary of the existing organization. The two summaries are then compared to determine whether the proposed plan will more effectively promote the chosen objective. A budget may be complete, proposing a reorganization of the whole firm, or partial, dealing with only a part of the farm business.

In order to determine the best plan out of all the alternatives, it would be necessary to apply the above technique to all possible plans. This "trial and error" method becomes impractical when the number of alternatives is large. As well, there remains some doubt as to whether the "best" plan arrived at is, in fact, the one which promotes the objective to the fullest extent. Thus, the farm budget has been largely limited to the analysis of part of the farm business where the number of alternatives is relatively small.

Linear Programming

The development of linear programming has overcome this overbearing computational burden of the complete budget. Described as a mathematical method of budgeting, linear programming employs the rapidity of the electronic computer to compare all possible plans, arriving at the one which maximizes the objective function.¹ (A computer program could conceivably be devised to computerize the technique of budgeting as described above. Conversely, a linear programming problem could be solved using a desk calculator. However, linear programming is more readily adaptable to the computer analysis of a large number of alternatives.) The vast saving in computational time, coupled with the element of certainty in arriving at the optimum solution makes linear programming a valuable innovation in the field of farm management analysis.

¹Linear programming is defined as the maximization (or minimization) of a linear function of variables which are subject to linear inequality or equality constraints. The general linear programming problem can be stated as:

$$\text{optimize} \quad z = \sum_{j=1}^n c_j x_j$$

$$\text{subject to} \quad \sum_{j=1}^n a_{ij} x_j \left\{ \begin{array}{l} \leq \\ = \\ \geq \end{array} \right\} b_i \quad (i = 1, \dots, m)$$

$$\text{and} \quad x_j \geq 0 \quad (j = 1, \dots, n)$$

The first equation is the objective function which is to be maximized (or minimized). For the purpose of this study, it is the expression of income (z) which is a function of the level of each

In fact, the types of problems to which linear programming can be applied are quite diverse. Any problem which exhibits the following quantifiable components can be expressed as a linear programming problem:

1. an objective,
2. alternative methods for attaining the objective, and
3. resource or other restrictions.

It can easily be demonstrated that this method of analysis is readily adaptable to static farm management problems. The objective (usually income maximization), alternative methods (crop, livestock activities), and resource restrictions are all quantifiable.

The problem analyzed in this study exhibits these three components. The objective function adopted is "net return over variable cost". In keeping with the principles of marginal analysis, fixed costs do not enter into determination of the optimum because

activity (x_j) and the income per unit of each activity (c_j). The level of income, z , is limited by the amounts of resources available (b_i), which inputs are used by the activities x_j in the amounts of a_{ij} per unit of output. The final inequality insures that no activity will enter the solution in a negative amount.

The following selected references will be of use to those who are unfamiliar with the technique:

Boulding, K. E. and W. A. Spivey, Linear Programming and the Theory of the Firm (New York: The MacMillan Co., 1961)

Garvin, W. W., Introduction to Linear Programming (New York: McGraw-Hill Book Co., 1960)

Heady, E. O. and W. Candler, Linear Programming Methods (Ames, Iowa: The Iowa State Press, 1963)

of the problem's short-run nature.² Alternative methods of attaining the objective consist of cropping, livestock, and other activities used in the model. The choice of these alternatives is limited by the resources and markets available and by subjective restrictions of management, all of which are expressed in the form of quantitative constraints.

Before beginning a description of the model employed, one more topic, which has relevance to the study, bears examination.

IV. THE CASE METHOD

The case study method lends itself best to the early, exploratory stages of research and is greatly useful in establishing, by analogy, trial hypotheses for empirical testing. It emphasizes the total situation or combination of factors. New relationships are discovered and described accurately only through exhaustive studies of this type. Every individual case has characteristics

²The theory of the firm states that equilibrium, or "the optimum" is reached when marginal cost is equal to marginal revenue. It is this point which is sought in employing the technique of linear programming. Marginal cost, by definition, encompasses only those costs which vary according to level of production--that is "variable costs". In a usual short-run situation, plant is assumed to remain at fixed capacity and marginal cost excludes "fixed costs" which represent costs incurred whether or not production is carried on. If the possibility of expanding fixed plant is included as an alternative course of action in reaching the optimum, then the fixed costs associated with the purchase of additional capacity must be treated as variable costs and must be included in the calculation of marginal cost.

which may be regarded as typical or representative of a large number of cases.

The case method has been described as the first step in scientific method, as opposed to the statistical method which is the best scientific procedure for classifying and summarizing large numbers of cases [19]. A case study, if accurate, is "always a true record of what occurs while a statistical generalization, except in those instances when all included cases are identified, is only an abstract approximation" [14, p. 233, quoting L. L. Bernard]. The case and statistical methods are, then, interdependent and complementary. The former "may on the one hand call attention to the problems to which the statistical method may be applied, and on the other hand may follow a statistical conclusion by a comprehensive analysis of the particular phenomenon which has been shown statistically to be a repetitious unit" [10, p. 123].

The procedure in a case study is to choose a case (in this study, a successful vegetable farm) and analyze all aspects of the case unit (examination of farm accounts, etc.), scrutinizing every seeming fact to make sure of actuality. "There is always a presumption that a case is to a certain extent unique ... but there is also a presumption that in many respects it is like other cases" [15, pp. 95-96]. It should be determined in what respects it is above, below, or at the norm. The case farm used in this study is unique in many respects and "representative" in others. These

considerations will receive more detailed analysis in a later chapter. For the present, it is emphasized that the farm under study is neither considered nor treated as completely representative of the vegetable farming industry in Manitoba.

In spite of this, inferences will be drawn from the case study in order to provide general recommendations for other production units. Although the case method exhibits a tendency to overemphasize unique characteristics of the particular case and the validity of generalizations may be distorted by the lack of data covering the spectrum upon which the study rests, the inferences drawn are not intended for rigorous application by vegetable growers at large. Rather they are designed as a general set of suggestions to provide a rough guide in planning farm business organization and to demonstrate what can be achieved through the use of linear programming. The solutions pertaining to the case farm itself will, on the other hand, possess rigor and will apply specifically to that farm.

CHAPTER III

THE ANALYTICAL MODEL

In one rather obvious sense, the point of employing a model belongs to the context of discovery rather than to that of validation; for models function as heuristic devices in science. [22, p. 25]

The purpose of this study is to develop a program of optimum response of a firm to changing conditions. Direct manipulations of an actual firm are impossible. This is overcome by constructing a mathematical model which represents the firm and upon which may be performed the appropriate manipulations.

I. DESCRIPTION OF THE STUDY FARM

The study farm is a commercial vegetable production unit located on Riverdale soil and comprising 245 cultivated acres. At present, this farm business is engaged exclusively in the production of vegetables on a commercial scale. The production pattern and per acre yields in 1966 are outlined in Table I.

Forage (clover) is grown for maintenance of soil texture so that a good seedbed may be prepared, and to promote good germination and root penetration (particularly in the case of table carrots where a straight root is desired for the fresh market). The forage is incorporated into the soil without harvesting a hay crop to provide a maximum of organic matter. Recommended fertilizer practices are followed. Canning carrots and onion sets are produced

under contract and the remainder of the vegetable crops are grown for the fresh market.

TABLE I
 PRODUCTION PATTERN AND MARKETABLE YIELD,
 CASE FARM, 1966

Crop	Acreage	Marketable yield per acre
	acres	tons
Table carrots	34	14
Canning carrots	20	25
Cooking onions	40	8
Pickle onions	9	4.5
Onion sets	10	7
Turnips	58	14
Cabbage	14	16
Parsnips	10	not available
Forage	<u>50</u>	-
Total acreage	245	-

All crops are seeded directly, eliminating the need for greenhouse facilities. Machinery utilized in producing the vegetable crops is mostly specialized for this purpose and is of the type common to most commercial vegetable farms. In particular, the harvesters employed are highly specialized, but are relatively

commonplace in this segment of commercial agriculture in Manitoba. Carrots, turnips, and cooking onions are harvested mechanically, while the rest of the vegetable crops are harvested mainly by hand labor.

As suggested earlier, labor requirements for these crops are very high. Yearly requirements per acre are listed in Table II.

TABLE II
YEARLY LABOR REQUIREMENTS PER ACRE,
VEGETABLE CROPS

Crop	Annual labor requirement
	man-hours
Table carrots	161.88
Canning carrots	82.36
Cooking onions	131.51
Pickle onions	308.97
Onion sets	288.31
Turnips	135.68
Cabbage	92.59

The figures in Table II include field operations (land preparation, seeding, cultivating, spraying, irrigation, harvesting), storage and grading operations, and machine repair. In 1966, the total labor

utilized on the study farm approached 27,000 man-hours, producing a total labor bill of more than \$37,000. A seasonal breakdown of labor requirements appears in Appendix A, Table A.1.

Storage facilities on the study farm are relatively elaborate as is necessitated by the storage requirements of vegetable products. Total capacity allows storage of up to 500 tons of onions plus 1672 tons of turnips or 860 tons of carrots. Products are graded before shipment and onions, carrots, and turnips are sold throughout the winter.

In terms of capital investment, the study farm is relatively large, compared to the average Manitoba farm business. However, vegetable production is characteristically a high investment area of agriculture and the case farm is more representative when compared to other commercial vegetable farms. Fixed assets totalled upwards of \$125,000 in 1966 and the firm exhibited a net worth of more than \$134,000.

II. THE CASE MODEL

The basic model uses the complement of resources present on the case farm as a starting point and, by variation of these resource levels, resource and product prices, and alternative activities considered, generates a pattern of optimum resource allocation which forms the basis for expansion policy recommendations.

Activities Employed

The case model is a mathematical representation of the case farm and employs activities, restrictions, price levels, and resource supplies which are appropriate to the study of that farm business.

The following is a list of the activities utilized in the case model:

<u>Number</u>	<u>Title</u>	<u>Unit</u>	<u>c_j</u>
1	Table carrots	acre	682.29
2	Canning carrots	acre	448.86
3	Cooking onions	acre	516.91
4	Pickle onions	acre	1504.92
5	Onion sets	acre	855.55
6	Turnips	acre	490.23
7	Cabbage	acre	348.19
8	Forage	acre	-11.79
9	Hire May labor	man-hour	-1.50
10	Hire June labor	man-hour	-1.50
11	Hire July labor	man-hour	-1.50
12	Hire August labor	man-hour	-1.50
13	Hire September labor	man-hour	-1.50
14	Hire October labor	man-hour	-1.50
15	Hire fall labor	man-hour	-1.50
16	Hire winter labor	man-hour	-1.50
17	Buy personal capital	dollar	-.03 ¹

¹All capital used for operating expenses is assumed to be tied up for an average time period of six months. Therefore, all operating capital used is assigned an interest charge amounting to one-half of the annual interest rate (activities 17, 18 and 19).

18	Buy operating capital @ 7.5%	dollar	-.0375
19	Buy operating capital @ 10%	dollar	-.05
20	May capital transfer	dollar	0.0
21	September capital transfer	dollar	0.0
22	October capital transfer	dollar	0.0
23	Use September generated capital	dollar	-.03
24	Use October generated capital	dollar	-.03
25	Use February generated capital	dollar	-.03
26	Buy investment capital @ 8.5%	dollar	-.085
27	Buy investment capital @ 10%	dollar	-.10
28	Stocker calf, cull ration	head	-198.97
29	Stocker calf, grain-hay ration	head	-207.15
30	Feeder steer, fall/cull ration	head	-218.96
31	Feeder steer, winter/cull ration	head	-218.96
32	Feeder steer, fall/grain-hay ration	head	-222.00
33	Feeder steer, winter/grain-hay ration	head	-222.00
34	Feeder steer, summer/grain-hay ration	head	-220.75
35	Sell slaughter steer	cwt.	24.85
36	Purchase cattle housing	head	-3.33
37	Purchase land up to 50 acres	acre	0.0
38	Rent land up to 50 acres	acre	-22.50
39	Purchase land over 50 acres	acre	0.0
40	Rent land over 50 acres	acre	-22.50
41	Purchase Scott Viner	hour	-2.44

42	Purchase onion harvesters	hour	-4.44
43	Purchase onion storage	sq. ft.	-.21
44	Purchase "general" storage	sq. ft.	-.23

Crop activities. (1--8). The case model includes seven vegetable crop alternatives and one forage activity. All vegetable crops are produced under irrigation and recommended fertilizer practices. Both of the carrot crops, cooking onions, and turnips are machine-harvested. Canning carrots and onion sets are produced under contract and the rest of the vegetable crops are sold on the fresh market.

The forage activity represents dutch clover which is incorporated into the soil without harvesting a crop.

Expected yields for the vegetable crops are shown in Table III.

TABLE III
EXPECTED YIELDS, VEGETABLE CROPS

Crop	Expected marketable yield	Cull yield (where relevant)
-- Tons --		
Table carrots	14	6
Canning carrots	25	4.4
Cooking onions	12	2
Pickle onions	6	
Onion sets	7	
Turnips	14	3.5
Cabbage	12	

Source: Yields are averages for the case farm and are considered to be those which would be attained under average growing conditions by following the cultural practices characterizing that farm. Cull yields are shown only for those crops for which such figures are required in the calculation of storage requirements and of cull supplies available for cattle feed.

Hire labor activities. (9--16). All labor is hired and eight activities provide for the purchase of labor services. The operator is assumed to act in the capacity of a manager only. During the growing season, labor services are broken down on a monthly basis, accounting for six activities (Hire May labor,, Hire October labor). The winter season is divided into two periods: November through January ("Fall") and February through April ("Winter"), to coincide with the livestock activities.

Operating capital activities. (17--25). An activity entitled "Buy personal capital" is included in the model to allow for the use of the operator's own capital for covering operating expenses. This activity is charged with an interest rate which represents the opportunity cost of using this capital for non-farm uses.

Augmenting this personally-owned capital, two other activities provide for borrowed operating capital. The first of these borrowing activities allows operating capital to be acquired up to a specified limit at a 7.5 per cent interest rate. The other permits additional operating capital to be borrowed up to a higher specified ceiling at 10 per cent.

Operating capital requirements for farming operations are not confined to the growing season. Provision is therefore made for operating capital demands in the fall and winter for feeder cattle, storage operations, etc. by three activities which allow operating capital to be transferred between periods. The model includes a

"May capital transfer" activity which permits capital to be transferred from May to September and "September" and "October" capital transfer activities allowing the transfer of capital from September and October to October and February respectively.

A second source of operating capital for fall and winter operations is represented by three activities termed "Use generated capital". These activities allow the use, for operating expenses, of funds generated by the sale of output.

Investment capital activities. (26, 27). It is assumed that all capital used for investment in fixed assets must be borrowed, and two activities are included in the model for this purpose. The first of these two activities allows investment capital to be borrowed up to a specified limit at an interest rate of 8.5 per cent. The other investment capital activity places a price of 10 per cent on capital borrowed over this ceiling.

Feeder cattle activities. (28--36). Feeder cattle alternatives included in the model comprise seven activities and are categorizable into two distinct types of feeder operations. The first type is termed "Stocker calf" and represents the purchase in October of a 400-pound calf which is fed throughout the winter and summer, and sold for slaughter in August at a weight of 1000 pounds. Two rations--one containing culled carrots and turnips and the other a conventional grain-hay ration--are available. The model therefore includes two stocker calf activities.

The second type of feeder cattle enterprise, called "Feeder steer", represents the purchase of a 700-pound yearling which is fed for four months and finished at 1000 pounds. To accommodate this type of enterprise, the year is divided into three periods: October through January ("Fall"), February through May ("Winter"), and June through September ("Summer"). By engaging in this enterprise during these three periods it is possible to finish three lots of beef cattle per year. For each of the first two periods, there is a possibility of feeding a ration containing culls or a conventional hay-grain ration, accounting for four activities. One additional activity is included to allow feeder steers to be finished during the June-September period. This activity is characterized by a conventional grain-hay ration since it is assumed that culled vegetables are not available for feeding during the summer months.

Costs, revenues, and resource requirements of the seven feeder cattle activities are tabulated in Appendix I.

Attendant to the feeder cattle activities are two others providing for the sale of finished animals and for the purchase of housing facilities.

The above thirty-six activities do not allow for the acquisition of additional quantities of the fixed resources already possessed by the farm firm under study. In order to analyze the effects of expansion of the fixed plant, several additional activities are included in the case model:

Land purchase and rental. (37--40). Two activities permit the acquisition of additional land--by an amount not exceeding 50 acres--without necessitating an increase in the machine complement. The inclusion in the solution of one or both of these two activities does not place additional demands on the investment capital supply for the purchase of machinery. An increase in the land resource of over 50 acres is attained by two supplementary land purchase and rental activities. These are identical to the previous two, except that they draw upon investment capital in an amount representing the purchase of additional machinery which is necessitated by the expansion of the land base in an amount exceeding 50 acres.

Mechanical harvester purchase. (41, 42). One activity permits the purchase of mechanical harvester capacity for carrots and turnips ("Scott Viner"), and another provides for the increase of onion harvester capacity.

Storage purchase. (43, 44). The model includes two types of storage facilities which are distinguishable mainly by different heating and ventilation requirements. One type is for use as onion storage and the other, termed "general" storage, is used to store table carrots and turnips. There are thus two activities available to increase storage capacity; one for each type.

Restrictions Utilized in the Model

The levels to which the above activities enter into the

optimum solution are limited by restraints which represent quantitative limits on the amounts of resources available and, in some cases, subjective restrictions in the interest of hedging against risk and uncertainty.

Fifty-four constraints are employed in the case model as outlined below:

<u>Number</u>	<u>Title</u>	<u>Unit</u>	<u>Initial restraint level (b_i)</u>
1	Land	acre	245.
2	Maximum land acquired	acre	255.
3	Maximum "free" land acquired	acre	50.
4	Percentage maximum table carrots	per cent	0.
5	Percentage maximum canning carrots	per cent	0.
6	Percentage maximum cooking onions	per cent	0.
7	Percentage maximum turnips	per cent	0.
8	Percentage maximum cabbage	per cent	0.
9	Percentage minimum forage	per cent	0.
10	Absolute maximum table carrots	acre	100.
11	Absolute maximum canning carrots	acre	50.
12	Absolute maximum cooking onions	acre	80.
13	Absolute maximum pickle onions	acre	10.
14	Absolute maximum onion sets	acre	10.
15	Absolute maximum turnips	acre	75.
16	Absolute maximum cabbage	acre	30.
17	May labor supply	man-hour	0.

18	June labor supply	man-hour	0.
19	July labor supply	man-hour	0.
20	August labor supply	man-hour	0.
21	September labor supply	man-hour	0.
22	October labor supply	man-hour	0.
23	Fall labor supply	man-hour	0.
24	Winter labor supply	man-hour	0.
25	Maximum May labor hired	man-hour	12500.
26	Maximum June labor hired	man-hour	12500.
27	Maximum July labor hired	man-hour	12500.
28	Maximum August labor hired	man-hour	12500.
29	Maximum September labor hired	man-hour	12500.
30	Maximum October labor hired	man-hour	12500.
31	Maximum fall labor hired	man-hour	37500.
32	Maximum winter labor hired	man-hour	37500.
33	Scott Viner capacity	hour	225.
34	Onion harvester capacity	hour	157.5
35	Onion storage capacity	sq. ft.	4320.
36	"General" storage capacity	sq. ft.	10320.
37	May operating capital supply	dollar	0.
38	September operating capital supply	dollar	0.
39	October operating capital supply	dollar	0.
40	February operating capital supply	dollar	0.
41	Personal capital supply	dollar	35000.

42	Maximum operating capital borrowed @ 7.5%	dollar	35000.
43	Maximum operating capital borrowed @ 10%	dollar	50000.
44	September generated capital	dollar	0.
45	October generated capital	dollar	0.
46	February generated capital	dollar	0.
47	Investment capital supply	dollar	0.
48	Maximum investment capital borrowed @ 7.5%	dollar	50000.
49	Maximum total investment capital borrowed	dollar	100000.
50	Slaughter steer supply	cwt.	0.
51	Fall housing capacity	head	0.
52	Winter housing capacity	head	0.
53	Summer housing capacity	head	0.
54	Culled vegetables supply	cwt.	0.

Land constraints. (1--3). The case model includes three land restraints. The first represents the amount of land (245 acres) presently cultivated by the farm operator. The second land restriction places a ceiling on the amount of land which may be acquired through the purchase and rental activities and reflects a subjective constraint of management. Also included is a restraint of 50 acres on the amount of land which can be acquired without being charged for additional machine investment.

Acreage constraints. (4--16). To account for rotational and hedging considerations of cropping, five constraints are included to restrict acreage of five of the vegetable crops to a maximum percentage of total acreage. As well, acreages of all vegetable crops are constrained by "absolute maximum" restrictions. These latter restraints represent market restrictions on the quantity of output which can be sold. A "minimum forage" constraint insures that forage acreage will be at least 25 per cent of the total acreage in crops in the optimal solution.

Conceptually, the percentage acreage constraints, as they appear in the initial simplex tableau, are more unusual than the other restrictions. They are most easily interpreted through their mathematical derivation. Constraint number four, for example, states that the acreage of table carrots must not exceed 30 per cent of the total cultivated acreage. Formulated mathematically:

$$x_1 \leq 0.3 \sum_{j=1}^8 x_j$$

That is, table carrot acreage (x_1) must be less than or equal to 30 per cent of the total acreage of all crops (x_1, \dots, x_8).

Then:

$$x_1 \leq 0.3x_1 + 0.3 \sum_{j=2}^8 x_j$$

$$x_1 - 0.3x_1 - 0.3 \sum_{j=2}^8 x_j \leq 0$$

$$0.7x_1 - 0.3 \sum_{j=2}^8 x_j \leq 0$$

This may be seen in the initial simplex tableau where the restraint level of row four is equal to zero, the input-output coefficient in the first column is 0.7, and the coefficients in columns two through eight are all -0.3 (see pages 37--40). The levels of these acreage restraints are summarized in Table IV.

TABLE IV
ACREAGE RESTRAINT LEVELS

Crop	Percentage restriction	Absolute maximum restriction
	per cent	acres
Table carrots	30 (maximum)	100
Canning carrots	20 (maximum)	50
Cooking onions	30 (maximum)	80
Pickle onions	-	10
Onion sets	-	10
Turnips	30 (maximum)	75
Cabbage	15 (maximum)	30
Forage	25 (minimum)	-

Labor constraints. (17--32). Eight restraints represent per-period labor supplies from which crop and livestock activities may draw. Eight more place maxima on the amount of labor which may be hired during each period. These latter restraints reflect the

amount of labor which would be available for hire at the wage rate utilized in the model.

Harvester capacity. (33, 34). Two restraints express the initial capacities of onion harvester and carrot-turnip harvester available. These capacities are used by carrots, onions, and turnips in the amounts shown in Table V, and may be supplemented by the "purchase harvester" activities.

TABLE V
MECHANICAL HARVESTER REQUIREMENTS PER ACRE

Activity	Scott Viner	Onion Harvester
	-- hours required --	
Table carrots	2.5	-
Canning carrots	2.5	-
Cooking onions	-	1.25
Turnips	2.0	-

Storage capacity. (35, 36). Similarly, the initial capacities of storage space for onions and for carrots and turnips are expressed by two restraints. These capacities may be supplemented by the "purchase storage" activities. Storage requirements of crop activities are outlined in Table VI.

TABLE VI
STORAGE REQUIREMENTS OF RELEVANT CROPS

	Unit	Table carrots	Cooking onions	Turnips
Total yield per acre	tons	20	14	17.5
Per cent of yield stored ¹	per cent	75	50	90
Amount stored per acre	tons	15	7	15.75
Space requirement per ton	sq. ft.	12	8.64	6.17
Storage space required per acre	sq. ft.	180	60.48	97.18

¹ It is assumed that 25 per cent of production in table carrots is sold at harvest and this portion has no storage requirement. Likewise, 50 per cent of the cooking onion crop and 10 per cent of the turnip output is sold before being placed in storage.

Capital constraints. (37--49). Six restraints govern the amount and utilization of operating capital. Operating capital supplies from which crop and livestock activities may draw are expressed as four restrictions which represent supplies of operating capital available for use during different periods of the year. That is, "May operating capital supply" signifies the supply of capital available for operating expenses over the period May through August; "September operating capital supply" is available to operations requiring capital during September; and so forth.

These supplies are drawn down by activities requiring operating capital and are supplemented by the sale of output, by borrowing activities, and by capital transfer activities.

Three "generated capital supply" restraints represent capital generated by the sale of output. This generated capital is made available for use in farm operations by being transferred into the above capital supplies by means of the "generated capital" activities. The maximum amounts of operating capital purchased (from the operator himself at 6 per cent, or on the open market at 7.5 per cent or 10 per cent) are specified by three other operating capital restrictions.

Investment capital is controlled by three restraints. The first expresses the supply, which is drawn down by activities representing the purchase of fixed assets and is contributed to by the "borrow investment capital" activities. The other two place ceilings on the amounts of investment capital which may be borrowed at the two rates of interest.

Feeder cattle constraints. (50--54). Feeder cattle activities contribute to a "Slaughter steer supply" constraint which is drawn on by the "Sell slaughter steer" activity. Three restraints represent housing space available during the three periods of the year during which cattle enterprises may be carried on. A restriction entitled "Culled vegetables supply" represents the supply of culls produced by the carrot and turnip activities.

The culls produced are available for cattle feed.

Summary Description of the Case Model

The case model is a mathematical representation of the alternatives open to the case farm and the restraints which limit the choice of these alternatives. The model is expressed as a linear programming problem consisting of a matrix having 54 rows and 44 columns. Beginning with this matrix, the model generates a linear programming solution which maximizes net income. Eight cropping activities and seven feeder cattle activities represent the production alternatives open to the farm business. The remaining 29 activities provide the opportunity to acquire additional fixed resources, transfer operating capital between periods, and sell output.

Resource requirements are calculated on a per-acre basis for crop activities and on a per-head basis for feeder cattle. These resource requirements form the main bulk of the input-output coefficients in the initial simplex tableau which is exhibited in Figure 1.

Description of Program Situations Pertaining to the Case Model

The objectives which relate to the case farm, as enumerated in Chapter II, are:

1. determination of the optimum combination of enterprises which is permitted by the set of resources present on the case farm in 1967;

			682.29	448.86	516.91	1504.92	855.55	490.23	348.19	-11.79	-1.50	-1.50	-1.50	-1.50		
Restriction Number and Title	Unit	Restriction Level (b ₁)	Activity Number and Title:												Row No.	
			1 Table Carrots	2 Canning Carrots	3 Cooking Onions	4 Pickle Onions	5 Onion Sets	6 Turnips	7 Cabbage	8 Forage	9 Hire May Labor	10 Hire June Labor	11 Hire July Labor	12 Hire Aug. Labor		
Unit:			acre	acre	acre	acre	acre	acre	acre	acre	acre	hour	hour	hour	hour	
1 Land	acre	245.	1.	1.	1.	1.	1.	1.	1.	1.	1.					1
2 Max. Land Acquired	acre	255.														2
3 Max. "Free" Land	acre	50.														3
4 % Max. Table Carrots	percent	0.	.7	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3					4
5 % Max. Canning Carrots	percent	0.	-.2	.8	-.2	-.2	-.2	-.2	-.2	-.2	-.2					5
6 % Max. Cooking Onions	percent	0.	-.3	-.3	.7	-.2	-.2	-.2	-.2	-.2	-.2					6
7 % Max. Turnips	percent	0.	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3					7
8 % Max. Cabbage	percent	0.	-.15	-.15	-.15	-.15	-.15	-.15	-.15	-.15	-.15					8
9 % Min. Forage	percent	0.	.25	.25	.25	.25	.25	.25	.25	.25	.25					9
10 Abs. Max. Tab. Carrots	acre	100.	1.													10
11 Abs. Max. Can. Carrots	acre	50.		1.												11
12 Abs. Max. Cook. Onions	acre	80.			1.											12
13 Abs. Max. Pick. Onions	acre	10.				1.										13
14 Abs. Max. Onion Sets	acre	10.					1.									14
15 Abs. Max. Turnips	acre	75.						1.								15
16 Abs. Max. Cabbage	acre	30.							1.							16
17 May Labor Supply	hour	0.	2.26	2.85	5.57	3.60	3.77	.79	1.							17
18 June Labor Supply	hour	0.	6.17	1.58	7.91	1.91	2.25	3.43	2.41							18
19 July Labor Supply	hour	0.	14.23	17.42	25.59	222.58	115.36	35.08	18.10							19
20 August Labor Supply	hour	0.	7.11	2.71	26.14	78.31	160.54	7.88	21.78							20
21 September Labor Supply	hour	0.	36.51	50.12	40.40	.09	4.59	10.49	10.80							21
22 October Labor Supply	hour	0.	39.84	.37	12.65	.09	.09	31.52	7.23							22
23 Fall Labor Supply	hour	0.	45.13	-3.93	4.79	1.08	1.08	-24.55	2.50							23
24 Winter Labor Supply	hour	0.	10.59	3.33	8.42	1.29	.63	21.91	.63							24
25 Max. May Labor Hired	hour	12500.														25
26 Max. June Labor Hired	hour	12500.														26
27 Max. July Labor Hired	hour	12500.														27
28 Max. Aug. Labor Hired	hour	12500.														28
29 Max. Sept. Labor Hired	hour	12500.														29
30 Max. Oct. Labor Hired	hour	12500.														30
31 Max. Fall Labor Hired	hour	37500.														31
32 Max. Winter Labor Hired	hour	37500.														32
33 Scott Viner Capacity	hour	225.	2.5	2.5				2.								33
34 Onion Harvester Cpty.	hour	157.5			1.25											34
35 Onion Storage Capacity	sq. ft.	4320.			60.48											35
36 "General" Storage Cpty.	sq. ft.	10320.	180.					97.17								36
37 May Operating Capital	dollar	0.	94.34	146.71	243.36	134.14	130.02	60.56	275.23	10.61	1.50	1.50	1.50	1.50		37
38 Sept. Operating Capital	dollar	0.	32.45	27.51	49.21	14.90	14.45	24.02	30.58	1.18						38
39 Oct. Operating Capital	dollar	0.	65.92	9.17	66.52			38.06								39
40 Feb. Operating Capital	dollar	0.						31.13								40
41 Personal Capital Supply	dollar	35000.														41
42 Max. Op. Capital @ 7.5%	dollar	35000.														42
43 Max. Op. Capital @ 10%	dollar	50000.														43
44 Sept. Generated Capital	dollar	0.	-25.84		-28.66	-575.50	-304.34		-83.98							44
45 Oct. Generated Capital	dollar	0.	-38.76	-316.11	-69.60	-447.57	-101.44	-27.60	-111.97							45
46 Feb. Generated Capital	dollar	0.	-361.79		-204.69			-124.19								46
47 Investment Capital	dollar	0.														47
48 Max. Inv. Cap @ 8.5%	dollar	50000.														48
49 Max. Total Inv. Cap.	dollar	100000.														49
50 Slaughter Steer Supply	cwt.	0.														50
51 Fall Housing Capacity	head	0.														51
52 Winter Housing Capacity	head	0.														52
53 Summer Housing Capacity	head	0.														53
54 Cull Supply	cwt.	0.	-120.	-88.				-70.								54

Figure 1. Initial simplex tableau of the case model.

		c _j :													
		-1.50	-1.50	-1.50	-1.50	-.03	-.0375	-.05	0.0	0.0	0.0	-.03	-.03	-.03	
Restraint Number	Activity Number and Title:	13 Hire Sept. Labor	14 Hire Oct. Labor	15 Hire Fall Labor	16 Hire Winter Labor	17 Buy Pers. Capital	18 Op. Cap. @ 7.5%	19 Op. Cap. @ 10%	20 May Cap. Transfer	21 Sept. Cap. Transfer	22 Oct. Cap. Transfer	23 Sept. Gen. Capital	24 Oct. Gen. Capital	25 Feb. Gen. Capital	Row No.
	Unit:	hour	hour	hour	hour	dollar	dollar	dollar	dollar	dollar	dollar	dollar	dollar	dollar	
1															1
2															2
3															3
4															4
5															5
6															6
7															7
8															8
9															9
10															10
11															11
12															12
13															13
14															14
15															15
16															16
17															17
18															18
19															19
20															20
21		-1.													21
22			-1.												22
23				-1.											23
24					-1.										24
25															25
26															26
27															27
28															28
29		1.													29
30			1.												30
31				1.											31
32					1.										32
33															33
34															34
35															35
36															36
37						-1.	-1.	-1.	1.			-1.			37
38		1.50							-1.	1.			-1.		38
39			1.50	1.50						-1.	1.			-1.	39
40					1.50						-1.				40
41						1.								-1.	41
42							1.								42
43								1.							43
44												1.			44
45													1.		45
46														1.	46
47															47
48															48
49															49
50															50
51															51
52															52
53															53
54															54

Figure 1. (continued).

Restraint Number	Activity Number and Title:	26 Buy Inv. Cap. 8.5%	27 Buy Inv. Cap. 10%	28 Calf-- Culls	29 Calf-- Grain-hay	30 Steer-- Fall/Culls	31 Steer-- Wntr/Culls	32 Steer-- Fall/Gr-hay	33 Steer-- Wntr/Gr-hay	34 Steer-- Summer	35 Sell Steer	36 Buy Housing	37 Buy Land up to 50 ac.	Row No.
Unit:	dollar	dollar	head	head	head	head	head	head	head	head	cwt.	head	acre	
1														1
2													-1.	2
3													1.	3
4													1.	4
5														5
6														6
7														7
8														8
9														9
10														10
11														11
12														12
13														13
14														14
15														15
16														16
17				.69	.69		1.45		1.4					17
18				.69	.69					.56				18
19				.69	.69					1.51				19
20				1.1	1.1					.92				20
21										1.35				21
22				.62	.62	.71		.61						22
23				2.86	2.47	4.07		3.93						23
24				2.64	2.25		3.33		3.14					24
25														25
26														26
27														27
28														28
29														29
30														30
31														31
32														32
33														33
34														34
35														35
36														36
37				32.49	35.21		15.37		16.15	217.87				37
38														38
39				133.73	136.45	216.08		219.12						39
40				29.87	32.61		200.71		202.97					40
41														41
42														42
43														43
44														44
45				-17.63	-10.28					-11.78				45
46						-12.94		-10.20						46
47		-1.	-1.									50.	237.50	47
48		1.												48
49		1.	1.											49
50				-9.7	-9.7	-9.8	-9.8	-9.8	-9.8	-9.8	1.			50
51				1.	1.	1.	1.	1.	1.	1.		-1.		51
52				1.	1.		1.		1.			-1.		52
53				1.	1.				1.			-1.		53
54				30.		52.5	52.5			1.				54

Figure 1. (continued).

Restraint Number	c _j :								Row No.
		-22.50	0.0	-22.50	-2.44	-4.44	-.21	-.23	
	Activity Number and Title:	38 Rent Land up to 50 ac.	39 Buy Land over 50 ac.	40 Rent Land over 50 ac.	41 Buy Scott Viner	42 Buy Onion Harvester	43 Buy Onion Storage	44 Buy General Storage	
Unit:	acre	acre	acre	hour	hour	sq. ft.	sq. ft.		
1									1
2		-1.	-1.	-1.					2
3		1.	1.	1.					3
4		1.							4
5									5
6									6
7									7
8									8
9									9
10									10
11									11
12									12
13									13
14									14
15									15
16									16
17									17
18									18
19									19
20									20
21									21
22									22
23									23
24									24
25									25
26									26
27									27
28									28
29									29
30									30
31									31
32									32
33					-1.				33
34						-1.			34
35							-1.		35
36								-1.	36
37		22.50		22.50					37
38									38
39									39
40									40
41									41
42									42
43									43
44									44
45									45
46									46
47			422.80	185.30	24.44	44.44	4.16	4.71	47
48									48
49									49
50									50
51									51
52									52
53									53
54									54

Figure 1. (continued).

2. to obtain an indication of the desirable course of expansion of the farm business when the above complement of resources is allowed to increase in magnitude and change in composition;
3. exploration of the possibility of introducing a feeder cattle enterprise into the farm business with a view to utilization of culled vegetables; and
4. determination of the effect of feeder cattle on the optima obtained in (1) and (2).

These objectives are fulfilled by using the case model to achieve several solutions. The following is a summary of the computer runs involving the case model:

Program 1. Objective 1 is attained by setting the restraints at levels which represent the quantities of fixed resources available on the case farm in 1967. Purchase and rental activities for land, harvesters, and storage are deleted so that no new fixed resources may be acquired. Feeder cattle activities are also deleted.

Program 2. This series of computer runs allows for the expansion of existing fixed resource capacities in order to promote the attainment of the second objective. Several runs are used to analyze the effects of allowing the purchase and rental of additional fixed resources. These runs are represented diagrammatically in Figure 2. Program 2 is composed of seven runs--each run incorporates a different combination of resource acquisition activities. Each run is identified by a lower-case Roman numeral as shown in Figure 2. Run v of Program 2, for example, represents the programming situation where the restraints are set at "base" levels (see "Program 1", above)

and activities are added to allow the purchase or rental of land and the purchase of mechanical harvester capacity.

Run	Resource Acquisition Activities Included:		
	Land	Storage	Harvesters
i	x		
ii		x	
iii			x
iv	x	x	
v	x		x
vi		x	x
vii	x	x	x

Figure 2. Computer runs used to analyze the effects of the expansion of supplies of fixed resources.

Land rentals and purchases are allowed to enter the optimal solutions at any level warranted by the economics of enterprise combination. Special constraints are added where relevant, however, to insure that storage purchases enter the solutions in amounts of at least 2400 square feet and harvester purchases enter in multiples of one machine.

Program 3. This program consists of eight computer runs which are identical to those contained in Programs 1 and 2 except that all runs of Program 3 include feeder cattle activities as production alternatives. This set of computer runs deals with objectives 3 and 4, and concludes the programming analysis segment of the case study.

Prior to discussing the solutions to the above programming situations, the measures used to generalize the model are described.

III. THE UNIVERSAL MODEL

The case model, as described above, yields solutions which are tenable for the case farm only. An attempt is made, therefore, to generalize the model so that similar results may be obtained for application to other commercial vegetable farms in Manitoba. This is accomplished by modifying the alternative activities, resource constraint levels, and input prices.

The "universal" model approximates conditions faced only by those farm businesses having storage facilities and machinery which are necessary for the production of the proposed crop alternatives on a commercial scale. Thus the model is "universal" only in the sense that it approximates the resource situation encountered by the larger commercial vegetable growers, from whose operations emanates, collectively, the greater proportion of output in Manitoba.

Activity Modifications

The scope of the model is widened by addition of two more cropping alternatives: celery and tomatoes. This addition makes the model more representative of the alternatives open to most commercial vegetable producers. Both crops can be produced with the complement of machinery which is assumed to exist in the model. Greenhouse requirements are eliminated by the purchase of transplants. Both crops are grown under irrigation and recommended fertilizer practices, as are the rest of the cropping alternatives. The remaining activities are identical to those used in the case model.

Costs, returns, yields, and resource requirements for tomatoes and celery are tabulated in Appendix A.

Resource Constraint Levels

Four constraints are added to the model to place ceilings of 15 per cent or 25 acres on the levels to which tomatoes and celery may enter the optimal solution.

Since capital and labor supplies are pertinent considerations in planning a vegetable cropping operation, the levels of restraints pertaining to these two resources receive detailed attention in the computer runs which employ the universal model. Several runs are executed, each incorporating a different combination of available capital and labor in order to approximate conditions faced by commercial vegetable growers in Manitoba. Figure 3 represents these

runs in diagrammatic form. Each lower-case Roman numeral denotes a resource situation characterized by a capital-labor combination signified by the row and column in which it appears. For example, run viii employs the capital-labor combination of \$30,000 operating capital, \$50,000 investment capital, and 5,000 man-hours of labor per month.

		Operating/Investment Capital Constraint Levels (dollars)	
		30000/50000	60000/80000
Labor Maxima/Month	20 men ¹ (5000 man-hours)	viii	xi
	35 men (8750 man-hours)	ix	xii
	50 men (12500 man-hours)	x	xiii

¹One man is assumed to contribute 10 hours per day, 25 days per month, or 250 man-hours per month to the labor supply.

Figure 3. Computer runs used in analyzing the effects of variation in availability of capital and labor.

Price Levels

The quantity of labor which is available for hire to a farm manager is dependent, in part, on the wage rate he is willing to pay. That is, a positively sloping labor supply function is assumed to exist so that higher levels of labor availability are associated with higher wage rates. The supply schedule shown in Table VII is a simple estimate intended as a rough approximation to conditions

as they appear to exist.

TABLE VII
LABOR SUPPLY SCHEDULE

Wage rate	Labor available per month
\$/hour	man-hours
1.20	5,000
1.35	8,750
1.50	12,500

Format of Programs Employing the Universal Model

In matrix form, the universal model is similar to the case model except that the former exhibits two additional activities and four more restraints. The programs outlined below, then, involve a basic matrix having 56 rows and 48 columns.

The programs dealing with the universal model are designed to promote the attainment of objective five which is restated here:

5. to compute optimum solutions for a broad range of resource levels in order to approximate other farm businesses in Manitoba whose area of specialization is vegetable crops, yet whose complement of resources and access to resources differ from the case farm.

As indicated above, attention is focussed mainly on resource constraint levels, with particular emphasis on the combinations of

capital and labor represented in Figure 3. Variation in resource availability within the group of commercial vegetable growers under study is significant and the aim here is to analyze the results of as many resource combinations as possible.

The programs involving the universal model include six runs each and are outlined in Figure 4.

Program Number	Initial Land Supply	Status of Feeder Cattle Activities
4	175 acres	deleted
5	245 acres	deleted
6	175 acres	included as production alternatives
7	245 acres	included as production alternatives

Figure 4. Computer programs involving the universal model.

All of the above programs include activities which provide for the purchase and rental of additional land, and the purchase, in integer amounts, of harvesters and storage facilities.

Initially, the capacity of each harvester is set at a level representing one machine of each type, and storage capacities are set at 4,320 square feet of onion storage and 8,640 square feet of "general" storage.

Figure 5 is a schematic representation of the computer runs employing the universal model.

Status of Livestock Activities	Initial Land Supply	Operating Capital/ Investment Capital	Labor Supply (man-hours)	Run No.	
Cattle Deleted	175 acres	\$30,000/50,000	5,000 8,750 12,500	viii ix x	Program 4
		\$60,000/80,000	5,000 8,750 12,500	xi xii xiii	
	245 acres	\$30,000/50,000	5,000 8,750 12,500	viii ix x	Program 5
		\$60,000/80,000	5,000 8,750 12,500	xi xii xiii	
Cattle Included	175 acres	\$30,000/50,000	5,000 8,750 12,500	viii ix x	Program 6
		\$60,000/80,000	5,000 8,750 12,500	xi xii xiii	
	245 acres	\$30,000/50,000	5,000 8,750 12,500	viii ix x	Program 7
		\$60,000/80,000	5,000 8,750 12,500	xi xii xiii	

Figure 5. Computer runs employing the universal model.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF RESULTS

The format of this chapter makes use of tables and narration to describe and interpret the solutions obtained from the computer programs outlined in the preceding chapter. In order to facilitate this explanation, a brief outline of the information yielded by the solution to a linear programming problem precedes the presentation of results.

I. INFORMATION YIELDED BY A LINEAR PROGRAMMING SOLUTION

The printed output which comprises the computer solution to a linear programming problem includes auxiliary information which assists in the interpretation of the optimum plan, as well as the optimum plan itself. The objective of linear programming is to find the optimum value of the objective function. This value comprises the first relevant datum in the solution. The optimum plan is of equal interest and is presented as a list of the levels of all activities entering into the solution.

The print-out also includes tabulation of the amounts of resources which are left unused and shadow prices of the limiting resources. The shadow prices are marginal values stating the amount by which the value of the functional would increase or decrease if the quantity of a limiting resource were raised or lowered by one

unit. For example, the following data for the land resource appear in an actual solution:

Shadow price	141.22
Lower limit	-3.10
Upper limit	13.52

These data are interpreted as follows: the value of the objective function could be increased in the amount of \$141.22 for each acre of land added to the land supply, up to a maximum of 13.52 additional acres (provided prices and all other constraint levels are constant). Likewise, a loss of \$141.22 per acre would be incurred if the land constraint level were decreased. This particular shadow price of \$141.22 applies only over the range denoted by the lower and upper limits; i.e. $245-3.10$ to $245+13.52$ acres; and only if all other parameters characterizing the particular run remain constant.

These data from the programming solutions are used in the interpretation of the results.

II. OPTIMUM PLAN FOR THE CASE FARM

The optima generated by the case model are tabulated in Tables VIII and IX. The lower-case Roman numerals designate the programming situations as described in Chapter III. Tables VIII and IX present the relevant data from the solution for each run: value of the functional, optimum plan, fixed assets acquired, resources used, unused resources, and shadow prices of limiting resources.

TABLE VIII
SOLUTION OUTLINES; PROGRAMS 1 AND 2

Unit	Program: Run:	1	2	2	2	2	2	2	2
			i	ii	iii	iv	v	vi	vii
Optimum Production Plan:									
Table Carrots	acres	57.33	57.33	57.33	57.33	57.33	16.84	73.50	100.00
Canning Carrots	acres	32.67	32.67	32.67	49.00	32.67	50.00	49.00	50.00
Cooking Onions	acres	71.43	71.43	73.50	57.42	80.00	71.43	41.25	71.43
Pickle Onions	acres	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Onion Sets	acres	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Turnips	acres	0.0	0.0	0.0	0.0	0.0	75.00	0.0	57.35
Cabbage	acres	2.32	30.00	.25	0.0	30.00	30.00	0.0	30.00
Forage	acres	<u>61.25</u>	<u>70.48</u>	<u>61.25</u>	<u>61.25</u>	<u>73.33</u>	<u>87.76</u>	<u>61.25</u>	<u>109.59</u>
Total Acreage in Crops	acres	245.00	281.91	245.00	245.00	293.33	351.03	245.00	438.37
Stocker Calf	head	-	-	-	-	-	-	-	-
Feeder Steer, Fall	head	-	-	-	-	-	-	-	-
Feeder Steer, Winter	head	-	-	-	-	-	-	-	-
Feeder Steer, Summer	head	-	-	-	-	-	-	-	-
Total Finished Beef Sold	cwt.	-	-	-	-	-	-	-	-
Resources Used:									
Labor: May	hours	715.04	783.94	721.58	678.03	832.38	805.24	624.57	984.83
June	hours	1069.45	1572.81	1048.34	942.34	1641.35	1611.91	914.17	2069.98
July	hours	6648.37	7252.10	6656.27	6523.78	7471.72	6610.17	6310.06	10176.46
August	hours	4824.78	5631.19	4818.64	4435.21	5855.52	5982.74	4127.43	6436.54
September	hours	6691.34	6990.85	6752.65	6918.81	7337.28	7169.11	6855.97	10021.37
October	hours	3221.85	3422.51	3233.07	3033.86	3531.08	4181.06	3473.54	6939.34
Fall	hours	3086.39	3155.82	3091.13	3077.66	3196.95	3238.46	3729.72	6558.15
Winter	hours	1338.95	1356.39	1355.10	1274.00	1428.60	2628.62	1309.09	3123.00
Total Operating Capital	dollars	88450.15	100877.46	101811.43	84635.33	105682.96	115582.34	82681.82	150126.18
Operating Capital Borrowed	dollars	20626.97	30298.55	20786.90	18583.49	33955.37	40200.52	14995.04	58476.21
Total Investment Capital	dollars	0.0	8764.88	10000.00	5499.99	21479.25	41063.79	19207.84	100000.00
Resources Left Unused:									
Land	acres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scott Viner	hours	0.0	0.0	0.0	184.17	0.0	132.89	143.75	185.29
Onion Harvester	hours	68.21	68.21	65.62	85.73	57.50	68.21	105.94	68.21
Onion Storage Space	sq. ft.	0.0	0.0	2274.72	847.44	1881.60	0.0	1825.20	0.0
"General" Storage Space	sq. ft.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gulled Vegetables	cwt.	9754.67	9754.67	9754.67	11192.00	9754.67	11671.12	13132.00	20414.81
Fixed Assets Acquired:									
Land Purchased	acres	-	36.91	-	-	48.33	106.03	-	0.0
Land Rented	acres	-	0.0	-	-	0.0	0.0	-	193.38
Scott Viner Purchased	hours	-	-	-	225.00	-	225.00	225.00	450.00
Onion Harvester Purchased	hours	-	-	-	0.0	-	0.0	0.0	0.0
Onion Storage Purchased	sq. ft.	-	-	2400.00	-	2400.00	-	0.0	0.0
"General" Storage Purchased	sq. ft.	-	-	0.0	-	0.0	-	2910.00	13253.56
Feedlot and Equipment	head	-	-	-	-	-	-	-	-
Shadow Prices of Limiting Resources:									
Land	\$/acre	141.69	-	173.62	224.34	-	-	227.84	-
Labor	\$/hour	-	-	-	-	-	-	-	-
Scott Viner	\$/hour	48.24	113.04	48.24	-	113.04	-	-	-
Onion Harvester	\$/hour	-	-	-	-	-	-	-	-
Onion Storage	\$/sq. ft.	1.76	4.44	-	-	-	4.00	-	3.03
"General" Storage	\$/sq. ft.	.62	.62	.62	.70	.62	2.06	-	-
Operating Capital	\$/dollar	-	-	-	-	-	-	-	-
Investment Capital	\$/dollar	-	-	-	-	-	-	-	.30
Optimum Value of the Objective Function	dollars	70,191.23	74,675.35	69,057.65	69,652.46	75,622.08	79,924.37	69,840.83	96,019.63

TABLE IX
SOLUTION (OUTLINES); PROGRAM 3

Unit	Programs Run:	3 o	3 i	3 ii	3 iii	3 iv	3 v	3 vi	3 vii
Optimum Production Plan:									
Table Carrots	acres	57.33	57.33	57.33	57.33	57.33	16.84	73.50	100.00
Canning Carrots	acres	32.67	32.67	32.67	49.00	32.67	50.00	49.00	50.00
Cooking Onions	acres	71.42	71.43	73.50	57.42	80.00	71.43	41.25	71.43
Pickle Onions	acres	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Onion Sets	acres	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Turnips	acres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cabbage	acres	2.32	30.00	.25	0.0	30.00	30.00	0.0	30.00
Forage	acres	61.25	79.48	61.25	61.25	73.33	87.76	61.25	102.98
Total Acreage in Crops	acres	245.00	281.91	245.00	245.00	293.33	351.03	245.00	411.91
Stocker Calf	head	325.16	325.16	325.16	373.07	325.16	356.43	437.73	187.87
Feeder Steer, Fall	head	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feeder Steer, Winter	head	77.07	46.85	109.56	74.70	115.44	18.63	87.94	200.01
Feeder Steer, Summer	head	77.07	46.85	72.36	74.70	42.82	0.0	32.20	0.0
Total Finished Beef Sold	cwt.	4664.61	4072.19	4936.85	5082.80	4509.02	3639.98	5423.42	3802.04
Resources Used:									
Labor: May	hours	1047.29	1073.88	1099.34	1040.02	1218.36	1079.05	1049.72	1390.08
June	hours	1336.97	1823.40	1313.22	1241.59	1878.49	1857.85	1234.24	2129.85
July	hours	6989.11	7547.19	6989.88	6893.98	7730.54	9856.11	6690.73	9609.09
August	hours	5253.36	6031.96	5242.88	4914.30	6234.19	6371.82	4638.56	6486.24
September	hours	6795.39	7054.09	6850.33	7019.65	7368.09	7169.11	6899.45	9812.67
October	hours	3423.45	3624.11	3434.67	3265.16	3732.68	4402.04	3741.93	6429.49
Fall	hours	4016.33	4085.77	4021.08	4144.64	4126.90	4257.85	4981.63	6607.90
Winter	hours	2439.37	2361.90	2557.55	2493.44	2649.50	3631.65	2740.83	356.64
Total Operating Capital	dollars	191446.98	190263.48	197961.78	196625.34	205176.99	194601.46	201710.86	226907.66
Operating Capital Borrowed	dollars	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00
Total Investment Capital	dollars	20111.35	27364.96	31736.16	27888.16	43509.10	59816.96	45491.38	100000.00
Resources Left Unused:									
Land	acres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scott Viner	hours	0.0	0.0	0.0	184.17	0.0	132.89	143.75	0.0
Onion Harvester	hours	68.21	68.21	65.62	85.73	57.50	68.21	105.94	68.21
Onion Storage Space	sq. ft.	0.0	0.0	2274.72	847.44	1881.60	0.0	1825.20	0.0
"General" Storage Space	sq. ft.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Culled Vegetables	cwt.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2783.38
Fixed Assets Acquired:									
Land Purchased	acres	-	36.91	-	-	48.33	106.03	-	0.0
Land Rented	acres	-	0.0	-	-	0.0	0.0	-	166.90
Scott Viner Purchased	hours	-	-	-	225.00	-	225.00	-	225.00
Onion Harvester Purchased	hours	-	-	-	0.0	-	0.0	-	0.0
Onion Storage Purchased	sq. ft.	-	-	2400.00	-	2400.00	-	0.0	0.0
"General" Storage Purchased	sq. ft.	-	-	0.0	-	0.0	-	2910.00	11324.16
Feedlot and Equipment	head	402.23	372.01	434.72	447.76	440.60	375.06	525.67	389.88
Shadow Prices of Limiting Resources:									
Land	\$/acre	135.55	-	165.04	220.39	-	-	233.18	-
Labor	\$/hour	-	-	-	-	-	-	-	-
Scott Viner	\$/hour	61.31	122.84	60.84	-	122.16	-	-	55.12
Onion Harvester	\$/hour	-	-	-	-	-	-	-	-
Onion Storage	\$/sq. ft.	1.63	4.17	-	-	-	3.40	-	3.31
"General" Storage	\$/sq. ft.	.57	.57	.58	.87	.57	1.88	-	-
Operating Capital	\$/dollar	.07	.07	.07	.07	.07	.11	.07	.11
Investment Capital	\$/dollar	-	-	-	-	-	-	-	.12
Optimum Value of the Objective Function	dollars	74,482.99	78,740.37	73,536.51	74,588.54	79,741.12	84,021.75	75,447.46	96,671.17

The optimum value of the objective function can not be taken as representing net income. As indicated in Chapter II, linear programming considers only variable operating costs when deriving optimum resource allocation if the fixed plant is assumed to be held at a constant capacity. Thus, fixed costs do not enter into the decision-making process in a short-run static situation. When consideration is given to the possibility of purchasing fixed resources to expand plant capacity, however, fixed costs must be taken into account. Activities depicting the purchase of additional fixed assets (storage facilities, machinery) are charged with a cost representing the fixed expense incurred through such an investment. Cropping and livestock activities, however, are charged with variable costs only.

Therefore, fixed costs associated with the initial plant capacity must be deducted from the optimum value of the objective function in order to arrive at the return to the fixed factors of production. The figure so calculated is termed "net income". Fixed overhead costs for the case farm are estimated at \$51,084.93.

In designing the programming situations, it was assumed that, when harvester capacity was allowed to be purchased, it must be purchased in amounts representing one machine (or multiples of one machine). It was necessary to eliminate the possibility of the purchase of fractional amounts of a machine. This was accomplished by adding appropriate constraints to the basic matrix.

to force the purchase of harvesters in integer amounts. Similarly, constraints were added where necessary to insure that storage facilities would be purchased in amounts no smaller than that representing 2400 square feet of floor area. Storage purchases of over 2400 square feet were allowed to assume fractional amounts. Land acquisition, however, was allowed to be carried on at any level promoting attainment of the optimum, and no special constraints were considered necessary to force its purchase (or rental) in integer amounts.

Program Solutions with Feeder Cattle Deleted

Table X summarizes the "net income" levels obtained by utilizing the case model to simulate the program situations designated by Program 1 and Runs i through vii of Program 2.

TABLE X

SUMMARY OF NET INCOME LEVELS DERIVED FROM PROGRAMS 1 AND 2

Program and run number	Optimum value of the objective function	Net income (net of fixed costs)
	\$	\$
Program 1	70,191.23	19,106.30
Program 2:		
Run i	74,675.35	23,590.42
Run ii	69,057.65	17,972.72
Run iii	69,652.46	18,567.53
Run iv	75,622.08	24,537.15
Run v	79,924.37	28,839.44
Run vi	69,840.83	18,755.90
Run vii	96,019.63	44,934.70

Program 1, as described in Chapter III, generates the optimum production plan when the plant is assumed to remain at constant capacity. When the acquisition of additional resources is not permitted, this optimal value of the objective function is \$70,191.23 which represents a net income of \$19,106.30. This income is achieved through the expenditure of \$88,450.15 for operating expenses, \$20,626.97 of which must be borrowed on the capital market. The data in Table VIII show that cropping pattern is influenced, and income is limited, by the fixed supplies of land, storage, and "Scott Viner" harvester available.

Program 2 was designed to study the effects of allowing the capacities of these limiting resources to expand, individually and in various combinations.

Examination of income levels generated by the runs of Program 2 reveals that the optima derived from the program situations characterizing Runs ii, iii, and vi are lower than the level obtainable from the "base" plant (Program 1). These three runs represent the situations in which harvester capacities and storage facilities are permitted to expand individually and together, while the land base is held at the initial level of 245 acres. The decline in income exhibited here is due to the requirement that storage and harvester capacities be purchased in integer amounts. Similar program situations which place no such restrictions, generate income levels which are slightly higher than that of Program 1.

The conclusion drawn is that income can not be increased by the expansion of storage and/or harvester capacities unless land is also acquired. Runs ii, iii, and vi of Program 2 are, therefore, rejected as being economically infeasible and their solutions will receive no further consideration. The following discussion, then, deals with those runs which generate an increase in income over that attainable from the base plant.

Run i. Introduction of land purchase and rental activities allows the case model to generate \$4,484.12 additional income over that attainable with the initial plant capacity. This rise in income is accomplished by the purchase of 36.91 acres of land which is utilized to increase the acreage of cabbage to 30 acres, the maximum allowed by the assumption of market limitation. Other vegetable crop acreages are limited by storage and harvester capacities or by acreage constraints.

Run iv. This program situation permits the acquisition of land and storage facilities. In computing the optimum, the model does not purchase "general" storage since acreages of the crops using this type of facility are constrained by "Scott Viner" harvester capacity. Onion storage purchase is forced into the solution at 2400 square feet, resulting in a rise in income as compared to that attained in Program 1. The income generated by Program 2, Run iv (\$24,537.15) results from an optimum plan featuring cooking onions and cabbage at levels representing their

respective market limitations. This is accomplished by the acquisition of adequate supplies of land and storage facilities.

Run v. A further expansion of income is made possible by the inclusion in the case model of activities providing the opportunity to acquire mechanical harvester capacities and land. In reaching the net income level of \$28,839.44, the model purchases 106.03 acres of land and one Scott Viner harvester.

It is interesting to note that, in this run for the first time, turnips enter the optimum production plan. This high level of turnip production is accompanied by a significant decline in table carrot acreage as compared to previous runs. Although turnips as a production alternative is less profitable on a per-acre basis than is table carrots, the former crop makes better use of scarce "general" storage capacity. This phenomenon occurs only when adequate supplies of land and harvesting equipment are available, so that storage facilities constitute the only physical restraint on production.

Run vii. The greatest income is generated when the case model includes activities which permit the acquisition of all three types of fixed assets. This situation results in a net income level of \$44,934.70 which is attained by the rental of 193.38 acres of land, the purchase of two Scott Viner harvesters, and the purchase of 13,253.56 square feet of "general" storage space. Land is rented rather than purchased in this situation because the limited

supply of investment capital is used up by the purchase of harvester and storage facilities. The majority of the vegetable crops are in the solution at levels designated by the absolute maximum market constraints--the exceptions being turnips and cooking onions, the levels of which are restrained by storage capacities and capital.

Summary of solutions to Programs 1 and 2. Run vii shows that the most profitable planning situation, in terms of net income, includes activities affording the opportunity to acquire all three types of fixed assets.

Runs iv and v generate only slight increases in net income over that attained by Run i in which land base alone is permitted to vary. Forcing storage and harvester capacities to be purchased in integer amounts results in a portion of these new resources going unused. The income levels involved may not be sufficient to induce management to carry on such purchase programs, considering the risk involved in using capital for unused capacities.

In short, in a static situation and within the limitations imposed by the assumptions of the case model, income is maximized by the purchase of two additional Scott Viner harvesters and 13,253.56 square feet of "general" storage space and the rental of 193.38 acres of additional land. If such a large expansion of plant capacity is considered to involve excessive risk, the production plan from one of Runs i, iv, or v should be considered as an alternate course of expansion of the farm business.

Program Solutions with Feeder Cattle Included

The introduction of feeder cattle activities as production alternatives in the case model has, with one exception, no effects on the optimum cropping patterns which were obtained through Programs 1 and 2. The exception is Run vii in which the inclusion of feeder cattle activities results in a decline in turnip acreage. This is caused by the demands of feeder cattle on scarce investment capital which is manifested in the model's ability to purchase only one Scott Viner harvester instead of two, as was the case in Run vii of Program 2. Therefore turnip acreage in the solution to Run vii of Program 3 is limited to a smaller acreage by mechanical harvester capacity.

Feeder cattle, then, appear to enter the solutions merely to use up resources left by the cropping enterprises. The pattern is predictable: in most cases the stocker calf activity enters the solution to utilize the supply of culled vegetables. Feeder steer activities, employing a grain-hay ration enter the solutions for the periods February through May and June through September at levels determined by available supplies of operating capital. A notable exception is the solution to Run vii, in which both feeder cattle enterprises utilize culls, yet there are culled vegetables left unused. This results from the high level of crop production which places high demands on capital and, at the same time, yields a large quantity of culls. The period October through January

("Fall") is noticeable in its lack of a feeder steer activity for any program situation. This is due to the peaking of operating capital demands by cropping activities during this period of the year.

Net income levels generated by the runs of Program 3 are listed in Table XI. The pattern of income levels corresponding to Program 3 has two differences from that associated with Programs 1 and 2. With feeder cattle enterprises included as production alternatives, gains in income can be obtained by the purchase of Scott Viner capacity, alone or in conjunction with "general" storage capacity. The income levels generated by the remaining runs of Program 3 bear the same relation to each other as do the solutions to Programs 1 and 2. The highest net income again is achieved by allowing the acquisition of all three types of fixed assets.

TABLE XI
SUMMARY OF NET INCOME LEVELS DERIVED FROM PROGRAM 3

Run number	Optimum value of the objective function	Net income (net of fixed costs)
	\$	\$
o	74,482.99	23,398.06
i	78,740.37	27,655.44
ii	73,536.51	22,451.58
iii	74,588.54	23,503.61
iv	79,741.12	28,656.19
v	84,021.75	32,936.82
vi	75,447.46	24,362.53
vii	96,671.17	45,586.24

III. OPTIMUM SOLUTIONS DERIVED FROM THE UNIVERSAL MODEL

The solutions to the computer runs employing the universal model are presented in detail in Appendix B. Figure 6 reproduces the schematic representation of the resource levels characterizing these runs, and summarizes the optimum values of the objective function obtained. Other solution data relevant to the present discussion are outlined in Tables XII, XIII, XIV, and XV.

Program Solutions with Feeder Cattle Deleted (Programs 4 and 5)

Discussion of solutions derived from the universal model proceeds by comparison of results obtained for a 175-acre farm and a 245-acre farm. Fixed overhead costs for these two production units are estimated at \$36,916.42 and \$42,314.68 respectively. In Tables XII and XIII, these costs have been deducted from the appropriate objective function values to arrive at net income figures for the various combinations of labor and capital as depicted in Figure 5.

Solution data for Programs 4 and 5 indicate that, under the assumptions of the model, the highest level of return to fixed factors of production can be achieved on a 245-acre farm having available to it 8750 man-hours of labor per month, \$60,000 operating capital, and \$80,000 investment capital (Program 5, Run xii). However, after deducting fixed costs, the 175-acre farm having the above combination of available resources achieves the highest net income.

Status of Livestock Activities	Initial Land Supply	Operating Capital/ Investment Capital	Labor Supply (man-hours)	Run Number		Optimum Value of the Objective Function (dollars)
Cattle Deleted	175 acres	\$30,000/50,000	5,000	viii	Program 4	60,893.61
			8,750	ix		59,355.83
			12,500	x		52,609.76
	245 acres	\$60,000/80,000	5,000	xi	Program 5	63,814.76
			8,750	xii		82,823.95
			12,500	xiii		75,090.78
Cattle Included	175 acres	\$30,000/50,000	5,000	viii	Program 6	61,878.74
			8,750	ix		60,499.00
			12,500	x		53,108.42
	245 acres	\$60,000/80,000	5,000	xi	Program 7	65,242.38
			8,750	xii		87,670.98
			12,500	xiii		79,592.65
175 acres	\$30,000/50,000	5,000	viii	Program 4	61,099.47	
		8,750	ix		59,373.01	
		12,500	x		52,609.76	
245 acres	\$60,000/80,000	5,000	xi	Program 5	65,895.10	
		8,750	xii		82,823.95	
		12,500	xiii		75,090.78	
175 acres	\$30,000/50,000	5,000	viii	Program 6	62,082.77	
		8,750	ix		60,499.00	
		12,500	x		53,108.42	
245 acres	\$60,000/80,000	5,000	xi	Program 7	66,602.02	
		8,750	xii		87,691.92	
		12,500	xiii		79,596.02	

Figure 6. Computer runs employing the universal model and optimum values of the objective function.

TABLE XII
SOLUTION DATA, PROGRAM 4

	Unit	Run:	viii	ix	x	xi	xii	xiii
<u>Optimum Production Plan:</u>								
Table carrots	ac.		64.55	63.96	58.80	68.76	96.55	94.12
Canning carrots	ac.		43.03	30.52	26.16	5.94	50.00	50.00
Cooking onions	ac.		0	0	0	41.17	41.22	29.79
Pickle onions	ac.		7.83	10.00	10.00	6.90	10.00	10.00
Set onions	ac.		0	7.58	8.74	0	10.00	10.00
Turnips	ac.		43.87	47.84	43.30	19.12	33.61	41.39
Cabbage	ac.		2.09	0	0	30.00	0	0
Tomatoes	ac.		0	0	0	0	0	0
Celery	ac.		0	0	0	0	0	0
Forage	ac.		53.79	53.30	49.00	57.30	80.46	78.44
Total acreage in crops	ac.		<u>215.16</u>	<u>213.20</u>	<u>196.00</u>	<u>229.19</u>	<u>321.84</u>	<u>313.74</u>
Stocker calf	head		-	-	-	-	-	-
Feeder steer, Fall	head		-	-	-	-	-	-
Feeder steer, Winter	head		-	-	-	-	-	-
Feeder steer, Summer	head		-	-	-	-	-	-
Total finished beef sold	cwt.		-	-	-	-	-	-
<u>Fixed Assets Acquired:</u>								
Land purchased	ac.		40.16	38.20	21.00	54.19	0	0
Land rented	ac.		0	0	0	0	146.84	138.74
Scott Viner purchased	hrs.		225.00	225.00	225.00	0	225.00	225.00
Onion harvester purchased	hrs.		0	0	0	0	0	0
Onion storage purchased	sq.ft.		0	0	0	0	0	0
"General" storage purchased	sq.ft.		7241.80	7521.08	6151.01	5594.66	12005.88	12324.43
Feedlot and equipment	head		-	-	-	-	-	-
Optimum value of the objective function	\$		60,893.61	59,355.83	52,609.76	63,814.76	82,823.95	75,090.78
Fixed overhead	\$		<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>
Net income	\$		<u>23,977.19</u>	<u>22,439.41</u>	<u>15,693.34</u>	<u>26,898.34</u>	<u>45,907.53</u>	<u>38,174.36</u>

TABLE XIII
SOLUTION DATA, PROGRAM 5

	Unit	Run:	viii	ix	x	xi	xii	xiii
<u>Optimum Production Plan:</u>								
Table carrots	ac.		65.28	65.10	58.80	70.54	100.00	96.79
Canning carrots	ac.		41.95	26.10	26.16	0	50.00	50.00
Cooking onions	ac.		0	0	0	45.58	42.63	33.69
Pickle onions	ac.		7.32	10.00	10.00	5.92	10.00	10.00
Set onions	ac.		0	7.24	8.74	0	10.00	10.00
Turnips	ac.		48.65	54.33	43.30	24.32	37.50	41.51
Cabbage	ac.		0	0	0	30.00	0	0
Tomatoes	ac.		0	0	0	0	0	0
Celery	ac.		0	0	0	0	0	0
Forage	ac.		54.40	54.25	49.00	58.79	83.38	80.66
Total acreage in crops	ac.		<u>217.60</u>	<u>217.02</u>	<u>196.00</u>	<u>235.15</u>	<u>333.51</u>	<u>322.65</u>
Stocker calf	head		-	-	-	-	-	-
Feeder steer, Fall	head		-	-	-	-	-	-
Feeder steer, Winter	head		-	-	-	-	-	-
Feeder steer, Summer	head		-	-	-	-	-	-
Total finished beef sold	cwt.		-	-	-	-	-	-
<u>Fixed Assets Acquired:</u>								
Land purchased	ac.		0	0	0	0	25.72	37.90
Land rented	ac.		0	0	0	0	62.79	39.75
Scott Viner purchased	hrs.		225.00	225.00	225.00	0	225.00	225.00
Onion harvester purchased	hrs.		0	0	0	0	0	0
Onion storage purchased	sq.ft.		0	0	0	0	0	0
"General" storage purchased	sq.ft.		7837.83	8358.42	6151.01	6421.35	13004.16	12816.60
Feedlot and equipment	head		-	-	-	-	-	-
Optimum value of the objective function	\$		61,878.74	60,499.00	53,108.42	65,242.38	87,670.98	79,592.65
Fixed overhead	\$		<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>
Net income	\$		<u>19,564.06</u>	<u>18,184.32</u>	<u>10,793.74</u>	<u>22,927.70</u>	<u>45,356.30</u>	<u>37,277.97</u>

TABLE XIV
SOLUTION DATA, PROGRAM 6

	Unit	Run:	viii	ix	x	xi	xii	xiii
<u>Optimum Production Plan:</u>								
Table carrots	ac.		63.92	63.83	58.80	61.89	96.55	94.12
Canning carrots	ac.		42.61	31.00	26.16	28.11	50.00	50.00
Cooking onions	ac.		.62	0	0	24.84	41.22	29.79
Pickle onions	ac.		7.90	10.00	10.00	9.87	10.00	10.00
Set onions	ac.		0	7.62	8.74	0	10.00	10.00
Turnips	ac.		44.75	47.13	43.30	0	33.61	41.39
Cabbage	ac.		0	0	0	30.00	0	0
Tomatoes	ac.		0	0	0	0	0	0
Celery	ac.		0	0	0	0	0	0
Forage	ac.		53.27	53.19	49.00	51.57	80.46	78.44
Total acreage in crops	ac.		<u>213.07</u>	<u>212.77</u>	<u>196.00</u>	<u>206.28</u>	<u>321.84</u>	<u>313.74</u>
Stocker calf	head		0	0	0	200.80	0	0
Feeder steer, Fall	head		29.45	10.63	0	0	0	0
Feeder steer, Winter	head		29.45	0	0	111.80	0	0
Feeder steer, Summer	head		0	0	0	0	0	0
Total finished beef sold	cwt.		577.28	104.20	0	3043.30	0	0
<u>Fixed Assets Acquired:</u>								
Land purchased	ac.		38.07	37.77	21.00	31.28	0	0
Land rented	ac.		0	0	0	0	146.84	138.74
Scott Viner purchased	hrs.		225.00	225.00	225.00	0	225.00	225.00
Onion harvester purchased	hrs.		0	0	0	0	0	0
Onion storage purchased	sq. ft.		0	0	0	0	0	0
"General" storage purchased	sq. ft.		7214.59	7429.36	6151.01	2499.45	12005.88	12324.43
Feedlot and equipment	head		29.45	10.63	0	312.60	0	0
Optimum value of the objective function	\$		61,099.47	59,373.01	52,609.76	65,895.10	82,823.95	75,090.78
Fixed overhead	\$		<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>	<u>36,916.42</u>
Net income	\$		<u>24,183.05</u>	<u>22,456.59</u>	<u>15,693.34</u>	<u>28,978.68</u>	<u>45,907.53</u>	<u>38,174.36</u>

TABLE XV
SOLUTION DATA, PROGRAM 7

Unit	Run:	viii	ix	x	xi	xii	xiii
<u>Optimum Production Plan:</u>							
Table carrots	ac.	64.54	65.11	58.80	69.13	99.76	96.73
Canning carrots	ac.	43.02	26.10	26.16	4.45	50.00	50.00
Cooking onions	ac.	0	0	0	42.33	41.84	33.52
Pickle onions	ac.	7.68	10.00	10.00	6.38	10.00	10.00
Set onions	ac.	0	7.24	8.74	0	10.00	10.00
Turnips	ac.	46.10	54.32	43.30	20.53	37.80	41.58
Cabbage	ac.	0	0	0	30.00	0	0
Tomatoes	ac.	0	0	0	0	0	0
Celery	ac.	0	0	0	0	0	0
Forage	ac.	53.78	54.25	49.00	57.61	83.13	80.61
Total acreage in crops	ac.	<u>215.12</u>	<u>217.02</u>	<u>196.00</u>	<u>230.43</u>	<u>332.53</u>	<u>322.44</u>
Stocker calf	head	0	0	0	80.52	0	0
Feeder steer, Fall	head	28.82	0	0	0	16.61	3.62
Feeder steer, Winter	head	16.93	0	0	173.21	16.61	3.62
Feeder steer, Summer	head	0	0	0	0	0	0
Total finished beef sold	cwt.	448.34	0	0	2478.54	325.53	70.92
<u>Fixed Assets Acquired:</u>							
Land purchased	ac.	0	0	0	0	23.26	37.37
Land rented	ac.	0	0	0	0	64.27	40.07
Scott Viner purchased	hrs.	225.00	225.00	225.00	0	225.00	225.00
Onion harvester purchased	hrs.	0	0	0	0	0	0
Onion storage purchased	sq.ft.	0	0	0	0	0	0
"General" storage purchased	sq.ft.	7456.17	8358.42	6151.01	5798.26	12990.01	12813.02
Feedlot and equipment	head	28.82	0	0	253.73	16.61	3.62
Optimum value of the objective function	\$	62,082.77	60,499.00	53,108.42	66,602.02	87,691.92	79,596.02
Fixed overhead	\$	<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>	<u>42,314.68</u>
Net income	\$	<u>19,768.09</u>	<u>18,184.32</u>	<u>10,793.74</u>	<u>24,287.34</u>	<u>45,377.24</u>	<u>37,281.34</u>

The least profitable combination of resources, on the other hand, is represented by Run x of Program 5 where 12,500 man-hours of labor per month, 245 acres of land, and \$30,000 and \$50,000 of operating capital and investment capital respectively yield a net income level of \$10,793.74.

Values of the objective function (and net income) are greatest when operating and investment capital are available in the amounts of \$60,000 and \$80,000 respectively (Runs xi, xii, and xiii). Under these conditions, labor availability of 8750 man-hours per month at a cost of \$1.35 per man-hour is most profitable and 5000 man-hours at \$1.20 results in the lowest return. If capital is more restricted (\$30,000/\$50,000), income rises as the wage rate declines (and labor availability decreases) for both acreage levels. At all levels of capital and labor, the 245-acre farm generates higher returns to fixed factors of production (values of the objective function). When fixed costs are deducted to calculate the "net income" figures, however, the 175-acre farm appears to have a slight advantage due to the lower overhead associated with the smaller land base.

Given an available labor supply of 5000 man-hours per month at a wage rate of \$1.20, net income is maximized by the resource combination of 175 acres of land, \$60,000 operating capital, and \$80,000 investment capital. The sequence of net income levels attained by setting labor supply at 5000 man-hours per month is shown in Table XVI. When labor supply is expanded to 8750 man-hours

per month at \$1.35, the income sequence is altered (see Table XVI). Raising the ceiling on labor supply, though wage rate is simultaneously increased, produces substantial gains in income when there is ample capital available. Lower capital supplies result in decreased income levels for both acreages.

TABLE XVI
SEQUENCES OF NET INCOME LEVELS GENERATED BY THE THREE MONTHLY SUPPLIES OF LABOR AND WAGE RATES

Program/Run	Operating/Investment capital available	Initial land supply	Net income
	\$	acres	\$
5000 man-hours per month at \$1.20			
4/xi	60,000/80,000	175	26,898.34
4/viii	30,000/50,000	175	23,977.19
5/xi	60,000/80,000	245	22,927.70
5/viii	30,000/50,000	245	19,564.06
8750 man-hours per month at \$1.35			
4/xii	60,000/80,000	175	45,907.53
5/xii	60,000/80,000	245	45,356.30
4/ix	30,000/50,000	175	22,439.41
5/ix	30,000/50,000	245	18,184.32
12500 man-hours per month at \$1.50			
4/xiii	60,000/80,000	175	38,174.36
5/xiii	60,000/80,000	245	37,277.97
4/x	30,000/50,000	175	15,693.34
5/x	30,000/50,000	245	10,793.74

At a level of 8750 man-hours per month, labor does not become restricting under any of the conditions imposed by the universal

model. Raising the ceiling on labor supply above this amount reduces income in all cases because of the associated higher wage rate. The data in Table XVI indicate that the capital supply is a prime factor in the determination of income, particularly at higher levels of labor supply and wage rate.

Neither tomatoes nor celery appear in any of the solutions. This is apparently the result of the high labor and operating capital requirements of these two crops. Table carrots enter the solutions at the peak allowed by acreage constraints and, in every case, this crop commands the highest acreage of any one cropping alternative. Cooking onions, an important crop in the case model, enters the "universal" solutions only when capital supplies are set at the higher levels (Runs xi, xii, and xiii). This is due to the relatively high operating capital requirement of cooking onions, compared to the crop's return.

The solutions in which cooking onions do not appear (Runs viii, ix, and x) would be reached if onion storage and harvester capacities were not included in the array of resources used in the model. Therefore, fixed costs associated with these assets could be deducted from the "fixed overhead" figure to yield a higher net income in the case of Runs viii, ix, and x of Programs 4 and 5.

Land acquisition occurs in all solutions for the 175-acre farm. At higher levels of capital and labor (Program 4, Runs xii and xiii), land is rented rather than purchased because investment

capital is used for the purchase of "general" storage capacity in large quantities. Expansion of the land base for the 245-acre farm occurs only at the high levels of capital and labor (Program 5, Runs xii and xiii). Therefore, it is profitable to expand the acreage of a 175-acre farm in the face of all conditions represented in the model, but increasing land base in the case of the 245-acre farm raises income only when there is available large quantities of labor as well as capital.

Since cooking onions acreage never reaches the level which would utilize all of the existing supply of onion harvester and storage, these two assets are not purchased in any of the solutions involving the universal model. However, one Scott Viner harvester is purchased in every resource situation except that represented by Run xi where labor availability is set at 5000 man-hours per month and capital supply is at the higher level (\$60,000/\$80,000). Under conditions simulated by this run, income is maximized by diverting production capabilities into cooking onions and cabbage rather than purchasing harvester capacity so that more carrots and turnips may be grown. "General" storage is purchased in all cases in order to accommodate substantial turnip and table carrot acreages.

Effects of Including Feeder Cattle as a Production Alternative

In almost one-half of the runs containing feeder cattle as an alternative, the enterprise is not included in the solution (see Tables XIV and XV). The solutions to these runs (x, xii, and

xiii of Program 6 and ix and x of Program 7) are identical to their counterparts in Programs 4 and 5. Checking back to Programs 4 and 5, the solutions indicate that, in these cases, operating capital supply is completely utilized by the cropping enterprises. Feeder cattle do not have a level of return which warrants diversion of operating capital from crop to livestock production.

There are certain cases, however, in which the feeder cattle enterprise appears able to compete for capital. For example, in Run viii of Programs 6 and 7 (both labor and capital supplies are at low levels) cattle activities enter the solution, slightly altering the cropping pattern. Acreage is reduced by 2.09 acres in Program 6 and by 2.48 acres in Program 7, and income increases in the amounts of \$205.86 and \$204.03 respectively. The same phenomenon occurs, to a lesser degree, in Program 6, Run ix and Program 7, Runs xii and xiii.

There are only two cases in which feeder cattle enter the optimum plan at significant levels. These two solutions are Run xi of Programs 6 and 7. In these situations, labor is assumed to be available in the amount of 5000 man-hours per month and capital supplies are set at the level of \$60,000 and \$80,000 operating and investment capital. The two runs are distinguished only by different initial acreage levels. As well as being the only two solutions to the universal model which include cattle at significant levels, they are unique in their inclusion of the stocker calf enterprise.

Checking back to Programs 4 and 5, the corresponding resource situations resulted in operating capital (and investment capital) going unused. This excess capital may be (and is) utilized for feeder cattle operations. In addition, the cattle enterprises appear to compete against crops for capital since, by the production of cattle, cropping patterns in Programs 6 and 7 (as compared to Programs 4 and 5) are altered. It is also interesting to note that these two runs are the only two situations under which cattle compete for capital during the growing season. This is, apparently, peculiar to the resource combination of low labor availability and relatively high capital supplies.

CHAPTER V

SUMMARY AND CONCLUSIONS

It is not the purpose of this study to delve into the standard arguments in support of, and criticizing, linear programming. Discussion of the advantages and shortcomings of the technique has reached such a stage that their treatment here would merely amount to a synopsis of the books and papers written on the topic. The reader is, therefore, referred to Dorfman [8] for an excellent criticism of linear programming with special emphasis on the limitations imposed by the basic assumptions of linearity, divisibility, finiteness, and additivity.

The linear programming approach aims at determining what farm organization would be "more profitable" or precisely, "the most profitable" under specific conditions. Thus, linear programming is a tool for normative analysis and is not intended as a means of predicting what adjustments in farm organization will actually occur. However, in light of the objectives, linear programming is considered an excellent tool for the analysis, since this study is of a normative nature.

Notwithstanding, the results of linear programming analysis are only as good as the model which is employed. How does the model compare, conceptually, to the actual conditions as they exist in the Manitoba vegetable industry?

Evaluation of the Model

The model used in this study is an attempt to approximate the operation of a firm engaged in the production of vegetables. Assuming that linear programming is a reliable and appropriate tool for analysis, the question remains as to the accuracy of the model in describing the operation of such a firm.

Technology assumed. Data for most of the cropping activities were obtained from the records of the study farm. Coefficients for tomatoes and celery were calculated from information gathered from various publications and experts in the field of vegetable production. Although detailed attention was given to the calculation of the input-output coefficients, it should be recognized that, by their nature, these coefficients fix the technical characteristics of production. Therefore, the technology in the model is given and constant, and application of the results to firms other than the case farm, even on a modest scale, should be done with due care and regard for this fact. However, the assumed technology is, apparently, a reasonably accurate approximation to production characteristics which are widespread among commercial vegetable producers of Manitoba, to whom this study is directed.

Similarly, the technical characteristics of feeder cattle production are given and constant. However, in most cases, each type of cattle enterprise offers a choice between two rations, thus providing some option in the selection of feeder cattle alternatives.

Price levels. Vegetable prices are four year averages (1964--1967) calculated from figures quoted in The Yearbook of Manitoba Agriculture [14]. More elaborate statistical methods could have been used to calculate expected prices but the time available did not allow such a detailed analysis. Any attempt at predicting commodity prices (and interest rates) is highly speculative, and it is recognized that the solutions are accurate only to the extent that actual prices approach those levels assumed in the model.

Resource supplies. Resource supply levels are varied to determine the optimum response of a farm firm to changing conditions. Of necessity, these quantities were changed in finite amounts to approximate a rough cross section of the group under study. The resource levels used in the case model represent the amounts of resources available to the study farm, but initial resource supplies assigned to the universal model are rather arbitrary and are not designed to correspond to any particular farm firm. Rather, the farm business represented by this set of resources is a hypothetical one, designed primarily for the purpose of testing the reaction of production patterns to varying conditions.

Therefore, practical application of the results to a particular farm business should be carried out with regard to how closely the farm in question approaches the situation defined by the resource levels used in the model. The results obtained in the

various runs of the universal model give a good indication of what occurs when the supply of one, or more, resource is expanded, and that is the context in which the results should be applied.

Static nature of the model. The model used in this study is essentially a static one in which the production, supply, and demand functions are all given and constant. Throughout this report, the underlying motivation for the inquiry has been the question of what adjustments a firm should make in the face of changing conditions. The emphasis has been on the adjustments which would counteract, or take advantage of, the new conditions--not how these adjustments may be achieved. That is, the analysis is "timeless", concerning itself with the farm organization before and after adjustment, but ignoring the processes through which the firm must pass in order to achieve the end result.

Nor does the study specify the time period over which these adjustments may, in practice, be accomplished. The implicit suggestion in the model is that the adjustment can be completed within one production year, but this need not be so. In many cases, the suggested reorganization is of such complexity that a firm may require several years to complete it.

Conclusions

The linear programming solutions to the model suggest the following general recommendations.

Under the conditions imposed by the assumptions of the model, the study farm can maximize income by expanding land base and mechanical harvester and storage capacities, as proposed in Chapter IV. This expansion in plant would permit the production of the cropping alternatives at levels shown in Table IX. In conjunction with this cropping program, a winter feeder steer operation and a stocker calf enterprise at levels of 200 head and 188 head respectively, are suggested.

More generally, the results from the "universal" model suggest an economic advantage in growing the root crops: table carrots, turnips, and canning carrots. To achieve the suggested levels of these crops, it is recommended that, under most resource situations considered, appropriate mechanical harvester and storage capacities be purchased. Cooking onions is a feasible alternative only when capital is available in relatively large amounts (for example, \$60,000 operating capital and \$80,000 investment capital). Pickle onions and sets are moderately good alternatives but are limited in scale of output by market availability. Cabbage is a poor alternative under most resource situations studied. Tomatoes and celery are not recommended because of the high labor and capital requirements of these two crops.

Labor directly limits production only when the ceiling of 5000 man-hours per month is placed on the labor supply. Of greater importance is the amount of cash which is available for payment as

wages. At higher levels of operating capital, higher wages can be paid, thus attracting ample quantities of labor.

Feeder cattle is a poor alternative, reaching significant levels only when there exists an excess supply of capital which is not utilized by cropping operations. A feeder cattle enterprise is able to compete for capital to some extent, but not enough to warrant the risk associated with setting up such an operation. Therefore, cattle are recommended only when a significant supply of idle capital is available which can not be put to use in the production of vegetables because of other (for example, market) limitations. This recommendation is supported by the solutions to the case model, where large supplies of capital allow more substantial feeder cattle production levels.

The factors effecting the optimum production pattern and income in agriculture are numerous and varied. Any attempt at simulation of a farm firm must take account of the effects, on the firm's operations, of all these factors. The difficulty of this task is compounded by the fact that most of these factors are in constant flux and vary independently of each other.

However, if the assumptions upon which the model is built are realistic and are specified, and if it is understood that the accuracy of the results is contingent upon how closely actual conditions approach those defined by the assumptions, then the exercise is useful in that it throws light on the fundamental economic

characteristics of production. The assumptions underlying the model used in this study have been specified and are regarded as a realistic reflection of conditions which characterize vegetable production in Manitoba.

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APPENDIX A

TABLE A.1

SEASONAL PER-UNIT LABOR REQUIREMENTS

Activity Number and Title	Annual Requirement	May	June	July	August	Sept.	Oct.	Fall	Winter
-- man-hours --									
1 Table Carrots	161.88	2.26	6.17	14.23	7.11	36.51	39.84	45.13	10.59
2 Canning Carrots	82.36	2.85	1.58	17.42	2.71	50.12	.37	3.93	3.33
3 Cooking Onions	131.51	5.57	7.91	25.59	26.14	40.40	12.65	4.79	8.42
4 Pickle Onions	308.97	3.60	1.91	222.58	78.31	.09	.09	1.08	1.29
5 Onion Sets	288.31	3.77	2.25	115.36	160.54	4.59	.09	1.08	.63
6 Turnips	135.68	.79	3.43	35.08	7.88	10.49	31.52	24.55	21.91
7 Cabbage	92.59	2.41	18.10	21.78	29.11	10.80	7.23	2.50	.63
8 Forage	.70	.23	.23	.07	.07	.05	.05		
45 Tomatoes	648.75	38.18	227.50	360.12	27.77	29.51	1.67		
46 Celery	621.80	20.17	44.33	82.75	252.15	222.40			
28 Stocker Calf, Culls	9.29	.69	.69	.69	1.10		.62	2.86	2.64
29 Stocker Calf, Grain-hay	8.51	.69	.69	.69	1.10		.62	2.47	2.25
30 Steer, Fall/Culls	4.78						.71	4.07	
31 Steer, Winter/Culls	4.78	1.45							3.33
32 Steer, Fall/Grain-hay	4.54						.61	3.93	
33 Steer, Winter/Grain-hay	4.54	1.40							3.14
34 Steer, Summer	4.34		.56	1.51	.92	1.35			

Note: To conserve space, data are expressed here to two decimal places. In the actual simplex tableau, four places were used. The above figures, when added across, may not be exactly equal to the totals shown.

TABLE A.2
PER-ACRE CROP EXPENSES

	Table Carrots	Canning Carrots	Cooking Onions	Pickle Onions	Onion Sets
-- dollars --					
Auto Repairs and Gas	17.00	17.00	17.00	10.00	10.00
Equipment Repairs	22.43	21.15	21.15	15.75	15.75
Fertilizer	0.0	0.0	22.52	12.47	20.00
Chemicals	10.30	17.50	40.50	13.85	33.00
Seed	10.15	0.0	31.25	28.69	45.00
Containers	0.0	0.0	75.00	49.88	0.0
Hydro, Propane	4.54	.50	30.00	0.0	0.0
Cartage, etc.	65.82	50.00	32.50	8.48	15.94
Miscellaneous	62.47	77.24	89.17	9.92	4.78
Variable Expenses less Labor and Interest	<u>192.71</u>	<u>183.39</u>	<u>359.09</u>	<u>149.04</u>	<u>144.47</u>
Labor at \$1.50 per hour	242.83	123.54	197.27	463.47	432.46
Total Cash Cost	<u>435.54</u>	<u>306.93</u>	<u>556.36</u>	<u>612.51</u>	<u>576.93</u>
Interest on Cash Cost at 3%	13.07	9.21	16.69	18.38	17.31
Total Variable Cost per Acre	<u>448.61</u>	<u>316.14</u>	<u>573.05</u>	<u>630.89</u>	<u>594.24</u>

TABLE A.2 (CONTINUED)

	Turnips	Cabbage	Forage	Tomatoes	Celery
-- dollars --					
Auto Repairs and Gas	17.00	10.00	5.00	9.00	10.00
Equipment Repairs	21.15	15.75	3.94	7.09	7.88
Fertilizer	0.0	26.07	0.0	31.48	39.91
Chemicals	5.17	7.14	0.0	14.81	78.50
Seed	.95	18.57	.75	126.44	650.00
Containers	2.33	161.43	0.0	152.83	200.00
Hydro, Propane	4.31	0.0	0.0	0.0	0.0
Cartage, etc.	62.07	51.89	.75	36.86	138.78
Miscellaneous	<u>40.79</u>	<u>14.96</u>	<u>1.35</u>	<u>74.57</u>	<u>114.34</u>
Variable Expenses less Labor and Interest	153.77	305.81	11.79	453.08	1239.41
Labor at \$1.50 per hour	<u>203.53</u>	<u>138.90</u>	<u>1.05</u>	<u>1027.12</u>	<u>932.70</u>
Total Cash Cost	357.30	444.71	12.84	1480.20	2172.11
Interest on Cash Cost	<u>10.72</u>	<u>13.34</u>	<u>.38</u>	<u>44.41</u>	<u>65.16</u>
Total Variable Cost per Acre	<u>368.02</u>	<u>458.05</u>	<u>13.22</u>	<u>1524.61</u>	<u>2237.27</u>

TABLE A.3
COSTS AND RETURNS, CROP ACTIVITIES

Activity Number and Title	Price per Ton	Expected Yield	Revenue per Acre	Cost per Acre ¹	c _j
	\$	tons	\$	\$	\$
1 Table Carrots	62.50	14	875.00	192.71	682.29
2 Canning Carrots	25.29	25	632.25	183.39	448.86
3 Cooking Onions	73.00	12	876.00	359.09	516.91
4 Pickle Onions	275.66	6	1653.96	149.04	1504.92
5 Onion Sets	142.86	7	1000.02	144.47	855.55
6 Turnips	46.00	14	644.00	153.77	490.23
7 Cabbage	54.50	12	654.00	305.81	348.19
8 Forage	-	-	0.0	11.79	-11.79
45 Tomatoes	153.50	11.2	1719.20	453.08	1266.12
46 Celery	94.00	30.5	2867.00	1239.41	1627.59

¹"Cost" here is equal to total variable cost less labor cost and interest on operating expenses.

TABLE A.4

PER-HEAD COSTS, FEEDER CATTLE ACTIVITIES

	28 Calf, Culls	29 Calf, Grain-hay	30 Steer, Fall/Culls	31 Steer, Wtr/Culls	32 Steer, Fall/Gr-hay	33 Steer, Wtr/Gr-hay	34 Steer, Summer
-- dollars --							
Veterinary Expenses	1.50	1.50	1.00	1.00	1.00	1.00	1.00
Bedding	3.00	3.00	1.75	1.75	1.75	1.75	.50
Buying Fee	.80	.80	1.40	1.40	1.40	1.40	1.40
Trucking "In"	1.04	1.04	1.77	1.77	1.77	1.77	1.77
Trucking "Out"	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Selling Fee	2.88	2.88	2.88	2.88	2.88	2.88	2.88
Feed	79.69	88.59	45.12	45.12	48.62	48.62	48.62
Miscellaneous ¹	6.44	5.80	3.50	3.50	3.05	3.05	3.05
	<u>97.95</u>	<u>106.21</u>	<u>60.02</u>	<u>60.02</u>	<u>63.07</u>	<u>63.07</u>	<u>61.82</u>
Less Death- Loss Allowance ²	.98	1.06	.31	.31	.32	.32	.32
	<u>96.97</u>	<u>105.15</u>	<u>59.71</u>	<u>59.71</u>	<u>62.75</u>	<u>62.75</u>	<u>61.50</u>
Purchase Price of Animal ³	102.00	102.00	159.25	159.25	159.25	159.25	159.25
<i>c_j</i>	<u>198.97</u>	<u>207.15</u>	<u>218.96</u>	<u>218.96</u>	<u>222.00</u>	<u>222.00</u>	<u>220.75</u>
Labor at \$1.50 per hour	13.94	12.76	7.17	7.17	6.81	6.81	6.51
Total Cash Cost	<u>212.91</u>	<u>219.91</u>	<u>226.13</u>	<u>226.13</u>	<u>228.81</u>	<u>228.81</u>	<u>227.26</u>
Interest on Cash Cost ⁴	10.50	10.85	4.46	4.46	4.52	4.52	4.49
Total Variable Cost per Head ⁵	<u>223.41</u>	<u>230.76</u>	<u>230.59</u>	<u>230.59</u>	<u>233.33</u>	<u>233.33</u>	<u>231.75</u>

Footnotes for Table A.4

¹"Miscellaneous" includes the cost of utilities, variable cost of miscellaneous machine use, feed grinding.

²Death loss allowance: death loss is assumed to be 2 percent in the case of "calf" activities and 1 percent for "steer" activities. This death loss is assumed to occur in the middle of the feeding period and, therefore, 1 percent and .5 percent of costs are deducted from the calf and steer activities respectively.

³Assumed purchase prices of animals are as follows:

Calf:	4 cwt. at \$25.50 per cwt. = \$102.00
Steer:	7 cwt. at \$22.75 per cwt. = \$159.25

⁴Interest on operating expenses: an interest rate of 6 percent per annum is assumed so that interest for the calf activities (of approximately 10 months duration) is calculated at 5 percent. For the steer activities, running 4 months, interest is calculated at 2 percent. Selling fees are not considered as being an expenditure which ties up capital and, therefore, do not enter into the interest calculations.

⁵This total variable cost figure is not used directly in the model, but enters into the calculation of "generated capital".

TABLE A.5
PER-HEAD FEED COSTS, FEEDER CATTLE ACTIVITIES

Feed Type	Amount Fed	Feed Cost
	pounds	dollars
<u>Ration I; Activity 28:</u>		
Culled Vegetables ¹	3000	6.00
Oats	1245	22.41
Barley	1072	22.73
Hay	2940	20.64
Minerals		2.75
Supplement	149.5	5.16
		<u>79.69</u>
<u>Ration II; Activity 29:</u>		
Oats	901	16.22
Barley	1952	41.39
Hay	3286	23.07
Minerals		2.75
Supplement	149.5	5.16
		<u>88.59</u>
<u>Ration III; Activities 30, 31:</u>		
Culled Vegetables ¹	5250	10.50
Oats	600	10.80
Barley	750	15.90
Hay	600	4.21
Minerals		1.25
Supplement	82	2.46
		<u>45.12</u>
<u>Ration IV; Activities 32, 33, 34:</u>		
Oats	495	8.91
Barley	1072	22.73
Hay	1890	13.27
Minerals		1.25
Supplement	82	2.46
		<u>48.62</u>

¹Culled vegetables used as cattle feed are assigned a value of \$4.00 per ton. This value represents the opportunity cost of selling the culls as feed for other cattle producers.

TABLE A.6
PER-HEAD REVENUE, FEEDER CATTLE ACTIVITIES

Activity Number	Yield per Head ¹	Sale Price per cwt.	Revenue per Head	TVC per Head ²	Return over TVC
	cwt.	\$	\$	\$	\$
28	9.7	24.85	241.04	223.41	17.63
29	9.7	24.85	241.04	230.76	10.28
30	9.8	24.85	243.53	230.59	12.94
31	9.8	24.85	243.53	230.59	12.94
32	9.8	24.85	243.53	233.33	10.20
33	9.8	24.85	243.53	233.33	10.20
34	9.8	24.85	243.53	231.75	11.78

¹All cattle are finished to 1,000 pounds. From this weight is deducted death loss allowance and tissue shrink as follows:

Calf activities: 2 percent death loss and 1 percent tissue shrink.

Steer activities: 1 percent death loss and 1 percent tissue shrink.

²Wage rate is assumed to be \$1.50 per hour.

TABLE A.7

SEASONAL OPERATING CAPITAL REQUIREMENTS, CROP AND LIVESTOCK ACTIVITIES

Activity Number and Title	Annual Capital Requirement per Unit ¹	Per-unit Operating Capital Requirement in:			
		May	September	October	February
-- dollars --					
1 Table Carrots	192.71	94.34	32.45	65.92	
2 Canning Carrots	183.39	146.71	27.51	9.17	
3 Cooking Onions	359.09	243.36	49.21	66.52	
4 Pickle Onions	149.04	134.14	14.90		
5 Onion Sets	144.47	130.02	14.45		
6 Turnips	153.77	60.56	24.02	38.06	31.13
7 Cabbage	305.81	275.23	30.58		
8 Forage	11.79	10.61	1.18		
45 Tomatoes	453.08	407.77	45.31		
46 Celery	1239.41	1115.47	123.94		
28 Stocker Calf, Culls	196.09	32.49		133.73	29.87
29 Stocker Calf, Grain-hay	204.27	35.21		136.45	32.61
30 Steer, Fall/Culls	216.08			216.08	
31 Steer, Winter/Culls	216.08	15.37			200.71
32 Steer, Fall/Grain-hay	219.12			219.12	
33 Steer, Winter/Grain-hay	219.12	16.15			202.97
34 Steer, Summer	217.87	217.87			

¹Exclusive of labor costs and interest on variable expenses.

TABLE A.8
GENERATED CAPITAL AT SELECTED WAGE RATES

Activity Number and Title	Total Generated Capital per Unit	Capital Generated in:		
		September	October	February
-- dollars --				
<u>\$1.50 wage rate:</u>				
1 Table Carrots	426.39	25.84	38.76	361.79
2 Canning Carrots	316.11		316.11	
3 Cooking Onions	302.95	28.66	69.60	204.69
4 Pickle Onions	1023.07	575.50	447.57	
5 Onion Sets	405.78	304.34	101.44	
6 Turnips	275.98		27.60	124.19
7 Cabbage	195.95	83.98	111.97	
45 Tomatoes	194.59	64.86	129.73	
46 Celery	629.73	209.91	419.82	
28 Stocker Calf, Culls	17.63		17.63	
29 Stocker Calf, Grain-hay	10.28		10.28	
30 Steer, Fall/Culls	12.94			12.94
31 Steer, Winter/Culls	12.94			
32 Steer, Fall/Grain-hay	10.20			10.20
33 Steer, Winter/Grain-hay	10.20			
34 Steer, Summer	11.78		11.78	
<u>\$1.35 wage rate:</u>				
1 Table Carrots	451.14	27.34	41.01	382.79
2 Canning Carrots	328.83		328.83	
3 Cooking Onions	323.27	30.58	74.26	218.43
4 Pickle Onions	1070.82	602.34	468.48	
5 Onion Sets	450.32	337.74	112.58	
6 Turnips	296.94		29.69	133.62
7 Cabbage	210.27	90.12	120.15	
45 Tomatoes	300.39	100.12	200.27	
46 Celery	725.80	241.91	483.89	
28 Stocker Calf, Culls	19.10		19.10	
29 Stocker Calf, Grain-hay	11.62		11.62	
30 Steer, Fall/Culls	13.67			13.67
31 Steer, Winter/Culls	13.67			
32 Steer, Fall/Grain-hay	10.90			10.90
33 Steer, Winter/Grain-hay	10.90			
34 Steer, Summer	12.50		12.50	

TABLE A.8 (CONTINUED)

Activity Number and Title	Total Generated Capital per Unit	Capital Generated in:		
		September	October	February
-- dollars --				
<u>\$1.20 wage rate:</u>				
1 Table Carrots	476.42	28.87	43.31	404.24
2 Canning Carrots	341.56		341.56	
3 Cooking Onions	343.58	32.50	78.92	232.16
4 Pickle Onions	1118.56	629.19	489.37	
5 Onion Sets	494.87	371.15	123.72	
6 Turnips	317.91		31.79	143.06
7 Cabbage	224.56	96.25	128.31	
45 Tomatoes	406.18	135.38	270.80	
46 Celery	821.86	273.92	547.94	
28 Stocker Calf, Culls	20.56		20.56	
29 Stocker Calf, Grain-hay	12.96		12.96	
30 Steer, Fall/Culls	14.39			14.39
31 Steer, Winter/Culls	14.39			
32 Steer, Fall/Grain-hay	11.60			11.60
33 Steer, Winter/Grain-hay	11.60			
34 Steer, Summer	13.11		13.11	

Note: Winter feeder steer activities (numbers 31 and 33) and turnips generate funds through the sale of output at the end of the planning period (May). These funds are not considered to be available for use during the current planning period and, therefore, are not included in the model as "generated capital". However, these funds contribute to income in the current planning period and presumably would be available for use in the following period.

APPENDIX B

TABLE B.1
SOLUTION DATA, PROGRAM 4

	Unit	Run:	viii	ix	x	xi	xii	xiii
Optimum Production Plan:								
Table Carrots	acres		64.55	63.96	58.80	68.76	96.55	94.12
Canning Carrots	acres		43.03	30.52	26.16	5.94	50.00	50.00
Cooking Onions	acres		0.0	0.0	0.0	41.17	41.22	29.79
Pickle Onions	acres		7.83	10.00	10.00	6.90	10.00	10.00
Onion Sets	acres		0.0	7.58	8.74	0.0	10.00	10.00
Turnips	acres		43.87	47.84	43.30	19.12	33.61	41.39
Cabbage	acres		2.09	0.0	0.0	30.00	0.0	0.0
Tomatoes	acres		0.0	0.0	0.0	0.0	0.0	0.0
Celery	acres		0.0	0.0	0.0	0.0	0.0	0.0
Forage	acres		53.79	52.30	49.00	57.30	80.46	78.44
Total Acreage in Crops	acres		215.16	213.20	196.00	229.19	321.84	313.74
Stocker Calf	head		-	-	-	-	-	-
Feeder Steer, Fall	head		-	-	-	-	-	-
Feeder Steer, Winter	head		-	-	-	-	-	-
Feeder Steer, Summer	head		-	-	-	-	-	-
Total Finished Beef Sold	cwt.		-	-	-	-	-	-
Fixed Assets Acquired:								
Land Purchased	acres		40.16	38.20	21.00	54.19	0.0	0.0
Land Rented	acres		0.0	0.0	0.0	0.0	146.84	138.74
Scott Viner Purchased	hours		225.00	225.00	225.00	0.0	225.00	225.00
Onion Harvester Purchased	hours		0.0	0.0	0.0	0.0	0.0	0.0
Onion Storage Purchased	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
"General" Storage Purchased	sq. ft.		7241.80	7521.08	6151.01	5594.66	12005.88	12324.43
Feedlot and Equipment	head		-	-	-	-	-	-
Resources Used:								
Labor: May	hours		349.92	347.20	322.82	528.04	710.66	647.19
June	hours		682.98	656.39	603.62	1395.61	1177.85	1098.65
July	hours		5000.00	6224.84	6049.60	5000.00	7865.37	7811.11
August	hours		1599.62	2918.97	3020.53	3149.88	4559.51	4304.72
September	hours		5000.00	4405.36	3956.03	5000.00	8100.23	7631.60
October	hours		3989.64	4072.29	3721.78	4086.17	5452.80	5456.64
Fall	hours		4173.66	4200.44	3840.14	3876.40	5599.32	5625.88
Winter	hours		1800.27	1845.41	1677.41	1541.99	2292.87	2341.33
Total Operating Capital	dollars		56632.20	61798.01	60905.30	72435.90	103207.42	103729.16
Operating Capital Borrowed	dollars		20000.00	20000.00	20000.00	23350.94	40000.00	40000.00
Total Investment Capital	dollars		49151.14	50000.00	39461.50	40000.00	80000.00	80000.00
Resources Left Unused:								
Land	acres		0.0	0.0	0.0	0.0	0.0	0.0
Scott Viner	hours		93.31	118.13	151.01	0.0	16.39	6.91
Onion Harvester	hours		157.50	157.50	157.50	106.04	105.98	120.26
Onion Storage	sq. ft.		4320.00	4320.00	4320.00	1830.06	1827.16	2517.97
"General" Storage	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
Culled Vegetables	cwt.		14603.46	13709.24	12388.73	10112.56	18339.21	18592.14
Shadow Prices of Limiting Resources:								
Land	\$/acre		-	-	-	-	-	-
Labor	\$/hour		6.79	-	-	6.23	-	-
Scott Viner	\$/hour		-	-	-	1.28	-	-
Onion Harvester	\$/hour		-	-	-	-	-	-
Onion Storage	\$/sq. ft.		-	-	-	-	-	-
"General" Storage	\$/sq. ft.		-	-	-	-	-	-
Operating Capital	\$/dollar		.31	1.32	1.20	-	.61	.56
Investment Capital	\$/dollar		-	.13	-	-	.20	.18
Optimum Value of the								
Objective Function	dollars		60,893.61	59,355.83	52,609.76	63,814.76	82,823.95	75,090.78
Fixed Overhead	dollars		36,916.42	36,916.42	36,916.42	36,916.42	36,916.42	36,916.42
Net Income	dollars		23,977.19	22,439.41	15,693.34	26,898.34	45,907.53	38,174.36

TABLE B.2
SOLUTION DATA, PROGRAM 5

	Unit	Run	viii	ix	x	xi	xii	xiii
<u>Optimum Production Plan:</u>								
Table Carrots	acres		65.28	65.10	58.80	70.54	100.00	96.79
Canning Carrots	acres		41.95	26.10	26.16	0.0	50.00	50.00
Cooking Onions	acres		0.0	0.0	0.0	45.58	42.63	33.69
Pickle Onions	acres		7.32	10.00	10.00	5.92	10.00	10.00
Onion Sets	acres		0.0	7.24	8.74	0.0	10.00	10.00
Turnips	acres		48.65	54.33	43.30	24.32	37.50	41.51
Cabbage	acres		0.0	0.0	0.0	30.00	0.0	0.0
Tomatoes	acres		0.0	0.0	0.0	0.0	0.0	0.0
Celery	acres		0.0	0.0	0.0	0.0	0.0	0.0
Forage	acres		54.40	54.25	49.00	58.79	83.38	80.66
Total Acreage in Crops	acres		217.60	217.02	196.00	235.15	333.51	322.65
Stocker Calf	head		-	-	-	-	-	-
Feeder Steer, Fall	head		-	-	-	-	-	-
Feeder Steer, Winter	head		-	-	-	-	-	-
Feeder Steer, Summer	head		-	-	-	-	-	-
Total Finished Beef Sold	cwt.		-	-	-	-	-	-
<u>Fixed Assets Acquired:</u>								
Land Purchased	acres		0.0	0.0	0.0	0.0	25.72	37.90
Land Rented	acres		0.0	0.0	0.0	0.0	62.79	39.75
Scott Viner Purchased	hours		225.00	225.00	225.00	0.0	225.00	225.00
Onion Harvester Purchased	hours		0.0	0.0	0.0	0.0	0.0	0.0
Onion Storage Purchased	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
"General" Storage Purchased	sq. ft.		7837.83	8358.42	6151.01	6421.35	13004.16	12816.60
Feedlot and Equipment	head		-	-	-	-	-	-
<u>Resources Used:</u>								
Labor: May	hours		345.53	341.23	322.82	540.63	730.10	675.55
June	hours		663.52	678.22	603.62	1448.47	1224.36	1146.88
July	hours		5000.00	6352.03	6049.60	5000.00	8087.19	7952.99
August	hours		1538.72	2910.92	3020.53	3226.39	4651.79	4426.55
September	hours		5000.00	4292.18	3956.03	5000.00	8324.08	7887.71
October	hours		4153.92	4321.04	3721.78	4374.75	5730.74	5616.09
Fall	hours		4313.96	4393.84	3840.14	4081.36	5857.14	5767.97
Winter	hours		1907.14	1984.79	1677.41	1690.76	2426.47	2404.96
Total Operating Capital	dollars		56993.36	62982.06	60905.30	74885.57	104838.63	104900.53
Operating Capital Borrowed	dollars		20000.00	20000.00	20000.00	27795.80	40000.00	40000.00
Total Investment Capital	dollars		42420.87	44873.17	34474.92	30248.41	80000.00	80000.00
<u>Resources Left Unused:</u>								
Land	acres		27.40	27.98	49.00	9.85	0.0	0.0
Scott Viner	hours		84.63	113.34	151.01	0.0	0.0	0.0
Onion Harvester	hours		157.50	157.50	157.50	100.53	104.21	115.39
Onion Storage	sq. ft.		4320.00	4320.00	4320.00	1563.45	1741.77	2282.59
"General" Storage	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
Culled Vegetables	cwt.		14930.50	13912.10	12388.73	10167.72	19025.00	18920.85
<u>Shadow Prices of Limiting Resources:</u>								
Land	\$/acre		-	-	-	-	-	-
Labor	\$/hour		7.09	-	-	6.42	-	-
Scott Viner	\$/hour		-	-	-	16.29	10.07	10.22
Onion Harvester	\$/hour		-	-	-	-	-	-
Onion Storage	\$/sq. ft.		-	-	-	-	-	-
"General" Storage	\$/sq. ft.		-	-	-	-	-	-
Operating Capital	\$/dollar		.42	1.59	1.34	-	.60	.58
Investment Capital	\$/dollar		-	-	-	-	.15	.15
<u>Optimum Value of the</u>								
Objective Function	dollar		61,878.74	60,499.00	53,108.42	65,242.38	87,670.98	79,592.65
Fixed Overhead	dollar		42,314.68	42,314.68	42,314.68	42,314.68	42,314.68	42,314.68
Net Income	dollar		19,564.06	18,184.32	10,793.74	22,927.70	45,356.30	37,277.97

TABLE B.3
SOLUTION DATA, PROGRAM 6

	Unit	Run:	viii	ix	x	xi	xii	xiii
<u>Optimum Production Plan:</u>								
Table Carrots	acres		63.92	63.83	58.80	61.89	96.55	94.12
Canning Carrots	acres		42.61	31.00	26.16	28.11	50.00	50.00
Cooking Onions	acres		.62	0.0	0.0	24.84	41.22	29.79
Pickle Onions	acres		7.90	10.00	10.00	9.87	10.00	10.00
Onion Sets	acres		0.0	7.62	8.74	0.0	10.00	10.00
Turnips	acres		44.75	47.13	43.30	0.0	33.61	41.39
Cabbage	acres		0.0	0.0	0.0	30.00	0.0	0.0
Tomatoes	acres		0.0	0.0	0.0	0.0	0.0	0.0
Celery	acres		0.0	0.0	0.0	0.0	0.0	0.0
Forage	acres		53.27	53.19	49.00	51.57	80.46	78.44
Total Acreage in Crops	acres		213.07	212.77	196.00	206.28	321.84	313.74
Stocker Calf	head		0.0	0.0	0.0	200.80	0.0	0.0
Feeder Steer, Fall	head		29.45	10.63	0.0	0.0	0.0	0.0
Feeder Steer, Winter	head		29.45	0.0	0.0	111.80	0.0	0.0
Feeder Steer, Summer	head		0.0	0.0	0.0	0.0	0.0	0.0
Total Finished Beef Sold	cwt.		577.28	104.20	0.0	3043.30	0.0	0.0
<u>Fixed Assets Acquired:</u>								
Land Purchased	acres		38.07	37.77	21.00	31.28	0.0	0.0
Land Rented	acres		0.0	0.0	0.0	0.0	146.84	138.74
Scott Viner Purchased	hours		225.00	225.00	225.00	0.0	225.00	225.00
Onion Harvester Purchased	hours		0.0	0.0	0.0	0.0	0.0	0.0
Onion Storage Purchased	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
"General" Storage Purchased	sq. ft.		7214.59	7429.36	6151.01	2499.45	12005.88	12324.43
Feedlot and Equipment	head		29.45	10.63	0.0	312.60	0.0	0.0
<u>Resources Used:</u>								
Labor: May	hours		389.26	347.86	322.82	777.80	710.66	647.19
June	hours		648.56	654.00	603.62	1336.24	1177.85	1098.65
July	hours		5000.00	6210.90	6049.60	5000.00	7865.37	7811.11
August	hours		1561.60	2919.84	3020.53	3037.09	4559.51	4304.72
September	hours		4967.96	4417.76	3956.03	5000.00	8100.23	7631.60
October	hours		4005.91	4052.59	3721.78	3135.56	5452.80	5456.64
Fall	hours		4283.05	4222.53	3840.14	3683.15	5599.32	5625.88
Winter	hours		1913.60	1830.14	1677.41	1885.68	2292.87	2341.33
Total Operating Capital	dollars		69095.30	64034.39	60905.30	129528.93	103207.42	104042.91
Operating Capital Borrowed	dollars		20000.00	20000.00	20000.00	40000.00	40000.00	40000.00
Total Investment Capital	dollars		50000.00	50000.00	39461.50	34833.89	80000.00	80000.00
<u>Resources Left Unused:</u>								
Land	acres		0.0	0.0	0.0	0.0	0.0	0.0
Scott Viner	hours		94.16	118.66	151.01	0.0	16.39	6.91
Onion Harvester	hours		156.72	157.50	157.50	126.44	105.98	120.26
Onion Storage	sq. ft.		4282.40	4320.00	4320.00	2817.48	1827.16	2517.97
"General" Storage	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
Culled Vegetables	cwt.		11460.58	13128.82	12388.73	0.0	18339.21	18592.14
<u>Shadow Prices of Limiting Resources:</u>								
Land	\$/acre		-	-	-	-	-	-
Labor	\$/hour		7.76	-	-	6.57	-	-
Scott Viner	\$/hour		-	-	-	13.96	-	-
Onion Harvester	\$/hour		-	-	-	-	-	-
Onion Storage	\$/sq. ft.		-	-	-	-	-	-
"General" Storage	\$/sq. ft.		-	-	-	-	-	-
Operating Capital	\$/dollar		.71	1.33	1.20	.11	.61	.56
Investment Capital	\$/dollar		.12	.13	-	-	.20	.18
<u>Optimum Value of the</u>								
Objective Function	dollars		61,099.47	59,373.01	52,609.76	65,895.10	82,823.95	75,090.78
Fixed Overhead	dollars		36,916.42	36,916.42	36,916.42	36,916.42	36,916.42	36,916.42
Net Income	dollars		24,183.05	22,456.59	15,693.34	28,978.68	45,907.53	38,174.36

TABLE B.4
SOLUTION DATA, PROGRAM 7

	Unit	Run:	viii	ix	x	xi	xii	xiii
<u>Optimum Production Plan:</u>								
Table Carrots	acres		64.54	65.11	58.80	69.13	99.76	96.73
Canning Carrots	acres		43.02	26.10	26.16	4.45	50.00	50.00
Cooking Onions	acres		0.0	0.0	0.0	42.33	41.84	33.52
Pickle Onions	acres		7.68	10.00	10.00	6.38	10.00	10.00
Onion Sets	acres		0.0	7.24	8.74	0.0	10.00	10.00
Turnips	acres		46.10	54.32	43.30	20.53	37.80	41.58
Cabbage	acres		0.0	0.0	0.0	30.00	0.0	0.0
Tomatoes	acres		0.0	0.0	0.0	0.0	0.0	0.0
Celery	acres		0.0	0.0	0.0	0.0	0.0	0.0
Forage	acres		53.78	54.25	49.00	57.61	83.13	80.61
Total Acreage in Crops	acres		215.12	217.02	196.00	230.43	332.53	322.44
Stocker Calf	head		0.0	0.0	0.0	80.52	0.0	0.0
Feeder Steer, Fall	head		28.82	0.0	0.0	0.0	16.61	3.62
Feeder Steer, Winter	head		16.93	0.0	0.0	173.21	16.61	3.62
Feeder Steer, Summer	head		0.0	0.0	0.0	0.0	0.0	0.0
Total Finished Beef Sold	cwt.		448.34	0.0	0.0	2478.54	325.53	70.92
<u>Fixed Assets Acquired:</u>								
Land Purchased	acres		0.0	0.0	0.0	0.0	23.26	37.37
Land Rented	acres		0.0	0.0	0.0	0.0	64.27	40.07
Scott Viner Purchased	hours		225.00	225.00	225.00	0.0	225.00	225.00
Onion Harvester Purchased	hours		0.0	0.0	0.0	0.0	0.0	0.0
Onion Storage Purchased	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
"General" Storage Purchased	sq. ft.		7456.17	8358.42	6151.01	5798.26	12990.01	12813.02
Feedlot and equipment	head		28.82	0.0	0.0	253.73	16.61	3.62
<u>Resources Used:</u>								
Labor: May	hours		370.62	341.23	322.82	835.80	749.40	679.76
June	hours		652.42	678.22	603.62	1464.18	1217.56	1145.43
July	hours		5000.00	6352.03	6049.60	5000.00	8074.00	7950.49
August	hours		1544.86	2910.92	3020.53	3238.37	4631.67	4422.32
September	hours		5000.00	4292.18	3956.03	5000.00	8286.34	7879.48
October	hours		4064.72	4321.04	3721.78	4209.32	5732.37	5616.50
Fall	hours		4339.71	4393.84	3840.14	4157.10	5917.44	5781.01
Winter	hours		1903.77	1984.79	1677.41	2365.22	2479.15	2416.62
Total Operating Capital	dollars		66531.56	62982.06	60905.29	128120.06	111836.89	106429.88
Operating Capital Borrowed	dollars		20000.00	20000.00	20000.00	40000.00	40000.00	40000.00
Total Investment Capital	dollars		42064.18	44873.17	34474.92	40000.00	80000.00	80000.00
<u>Resources Left Unused:</u>								
Land	acres		29.88	27.98	49.00	14.57	0.0	0.0
Scott Viner	hours		88.90	113.34	151.01	0.0	0.0	0.0
Onion Harvester	hours		157.50	157.50	157.50	104.59	105.20	115.60
Onion Storage	sq. ft.		4320.00	4320.00	4320.00	1760.07	1789.79	2292.76
"General" Storage	sq. ft.		0.0	0.0	0.0	0.0	0.0	0.0
Culled Vegetables	cwt.		12355.52	13912.10	12388.73	0.0	17273.25	18538.95
<u>Shadow Prices of Limiting Resources:</u>								
Land	\$/acre		-	-	-	-	-	-
Labor	\$/hour		7.86	-	-	6.68	-	-
Scott Viner	\$/hour		-	-	-	11.55	14.26	10.04
Onion Harvester	\$/hour		-	-	-	-	-	-
Onion Storage	\$/sq. ft.		-	-	-	-	-	-
"General" Storage	\$/sq. ft.		-	-	-	-	-	-
Operating Capital	\$/dollar		.74	1.59	1.34	.11	.64	.58
Investment Capital	\$/dollar		-	-	-	-	.16	.15
<u>Optimum Value of the Objective Function</u>								
Objective Function	dollars		62,082.77	60,499.00	53,108.42	66,602.02	87,691.92	79,596.02
Fixed Overhead	dollars		42,314.68	42,314.68	42,314.68	42,314.68	42,314.68	42,314.68
Net Income	dollars		19,768.09	18,184.32	10,793.74	24,287.34	45,377.24	37,281.34