MASSEY UNIVERSITY

A LINEAR PROGRAMMING APPROACH TO THE EVALUATION OF ORCHARD ADJUSTMENT STRATEGIES

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Technical Discussion Paper No. 14
DEPARTMENT OF AGRICULTURAL ECONOMICS
AND FARM MANAGEMENT
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Preface

In 1975/76 an economic survey of the New Zealand Pip Fruit Industry was conducted by Mr P.P. Oppenheim, Lecturer in Horticultural Management at Massey University. This survey revealed the emergence of a low income problem in a sector of the pip fruit industry near Nelson. In order to study this problem, Mr Oppenheim constructed an intertemporal linear programming model of a representative Nelson orchard. While the model was originally constructed for the analysis of rural policy, the purpose of this paper is confined to an exposition of the structure and the results that were obtained from experimentation with the model.

Because of the extensive amount of data required to specify the intertemporal model, it was decided to exclude appendices containing data relating to the model. All such data is, however, freely available upon request from Mr Oppenheim.

I would like to thank all those persons and organisations who contributed to this study. In particular, I would like to record the guidance and advice given by Dr A.N. Rae and Professor R.J. Townsley. I am also grateful to the New Zealand Fruit Growers Federation and the New Zealand Apple and Pear Board for permission to use survey data.

I hope that interested readers will be stimulated to consider the practical applications of the model presented in this paper. Mr Oppenheim would welcome comment and constructive criticism.

A.R. Frampton.

Head of Department of Agricultural
Economics and Farm Management.

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ABSTRACT

A ten year intertemporal linear programming model of an orchard farming system was constructed in order to study and derive feasible adjustment strategies. The model was based on an orchard representative of those experiencing adjustment problems and provided for the adoption of new enterprises in addition to a variety of replanting, reworking, interplanting and tree removal activities.

The results obtained from experimentation with the model included optimal patterns of tree replacement and intertemporal cash flows. These results indicated that the financial position of Moutere Hill pip fruit producers would continue to deteriorate over the next decade with considerable borrowing being required to finance maintenance and/or developmental expenditure. Positive cash flows could be expected towards the end of the 1980's after which the benefits of orchard restructuring would continue to accrue.

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1.0 Introduction

Pip fruit production, in terms of export earnings and the number of growers engaged in the industry, rates as New Zealand's largest horticultural industry. In 1975/76 the New Zealand Pip Fruit Industry produced 176 822 tonnes of apples and pears of which 71 600 tonnes were exported earning $19.2 million (f.o.b.) in export receipts. Although this represents only a small percentage of New Zealand's total export earnings for 1975/76, it does form a significant contribution to the welfare of the nation.

While pip fruit may be grown throughout New Zealand, 49.7 percent[1/] of the total area planted to apples and pears is centred about Hastings and Nelson. For many years the Nelson Province has been the major region involved in the production of pip fruit, particularly for the export market. The production and export value of the Nelson apple crop, which accounts for 95% of the region's pip fruit production, is summarised in table 1.1.

In 1975/76, 205 orchardists in the Nelson Province produced more than 56 000 tonnes of apples and 2700 tonnes of pears. This represented 32.7 percent of the total New Zealand pip fruit crop and 23 percent of the value of that province's agricultural production.[2/] The Nelson pip fruit industry may therefore be viewed as one of both national and regional importance.

1/ Report on the Official Survey, New Zealand Fruit Growing Industry 1973.

2/ M.A.F. Estimate of the Value of Production in Waimea and Golden Bay Counties, March 1975.

Table 1.1 Nelson Apple Exports ($ million f.o.b.)

Year	Production		Exports		Value	
	N.Z. total[b] ('000 tonnes)	Nelson[b] (%)	N.Z. total[a] ('000 tonnes)	Nelson[b] (%)	N.Z.[a] ($'m) f.o.b.	Nelson[c] ($'m) f.o.b.
1969	106.9	47.6	54.6	45.6	8.9	4.06
1970	133.7	40.5	52.1	57.0	8.6	4.90
1971	120.7	45.0	58.1	50.0	10.4	5.20
1972	149.4	38.4	66.8	52.5	12.9	6.77
1973	143.1	37.4	66.3	47.9	12.8	6.13
1974	152.1	39.8	79.6	43.7	18.1	7.91
1975	159.4	38.0	71.6	49.5	19.2	9.50

Source: (a) 1969/70 - 1975/76 N.Z. Department of Statistics.

(b) M.A.F. Horticultural Statistics.

(c) Computed from the average N.Z. f.o.b. earnings/tonne.

In recent years, however, there has been a decline in the level of income of Nelson pip fruit producers. The following table compares the net income of pip fruit producers in Hawkes Bay with the three regions involved in pip fruit production in the Nelson Province for the years 1972/73 to 1974/75:

Table 1.2 Pip Fruit Growers Net Income[a)] 1972/73 to 1974/75 ($)

Year	Hawkes Bay	Nelson	Mapua	Motueka	New Zealand
1972/73	8 411	4787	5295	14 841	7536
1973/74	11 598	4383	4196	11 559	8292
1974/75	13 283	3153	3919	13 974	9172

a) Net Income = gross farm and off farm receipts less cash costs and depreciation.

Source: Rae, A.N. et al. [18]

In addition, extensive plantings of semi-intensive orchards and increased productivity in Hawkes Bay since 1965 have slowly eroded the prominent position the Nelson Province once occupied. As a result the quantity of pip fruit submitted to the Apple and Pear Board from the Nelson Province has fallen during the period 1970-76, from 48 percent to 44 percent of the Board's total receipts. Over the same period, the contribution from Hawkes Bay has increased from 30 to 41 percent.[3/]

The deteriorating position of the Nelson Pip Fruit Industry is therefore a twofold problem. First, it is a problem of national importance as 50 percent of the nation's export income from pip fruit is derived from this province. Secondly, it is a problem of regional significance as the emergence of rural poverty in a sector of the agricultural community is likely to have a significant effect on other sectors in Nelson Province.

3/ The New Zealand Apple and Pear Marketing Board, 28th Annual Report 1976.

Against this background, it was decided to construct an intertemporal linear programming (I.L.P.) model of orchard production. The model was based on an orchard representative of those experiencing financial problems on the Moutere Hills and therefore reflects the constraints facing the managers of such enterprises. The objective of the exercise was to examine and evaluate a variety of alternative adjustment strategies available to managers of Moutere Hill Orchards in order to derive a set of feasible adjustment plans. In this paper I.L.P. model is discussed and the results which were obtained from experimentation with the model are presented.

2.0 The Intertemporal Linear Programming Model[1/]

2.1 Features of the Intertemporal Model

Although there is essentially no difference between the static single period linear programming model (L.P.) and the intertemporal variant, there are a number of features which differentiate the I.L.P. from the ordinary L.P. Olsson [14] lists these features as follows:

1. Each activity and each constraint must be dated in a certain period of time.
2. Cash flows of income and expenditure occur in the model instead of the revenues and costs included in the static model.
3. For each activity dated in a certain period of time, not only is there a link between this activity and the constraint in the same period, but also the possible link with constraints in other periods.

Thus the general form in which L.P. problems are described, namely

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1/ The following synonyms are often encountered in the literature: Multiperiod, polyperiod, multistage and dynamic linear programming.

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

$$\text{Subject to } \sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

$$x_j \geq 0 \text{ for all } j = 1, 2, \ldots, n$$
$$i = 1, 2, \ldots, m$$

may be rewritten to represent an I.L.P. problem as:

$$\text{Maximise } Z = \sum_{j=1}^{n} c_j^1 x_j^1 + \sum_{j=1}^{n} c_j^2 x_j^2 + \ldots + \sum_{j=1}^{n} c_j^T x_j^T$$

$$\text{Subject to } \sum_{j=1}^{n} a_{ij}^1 x_j^1 \leq b_i^1$$

$$\sum_{j=1}^{n} a_{ij}^2 x_j^1 + \sum_{j=1}^{n} a_{ij}^1 x_j^2 \leq b_i^2$$

$$\vdots \qquad \vdots \qquad \ddots$$

$$\sum_{j=1}^{n} a_{ij}^T x_j^1 + \sum_{j=1}^{n} a_{ij}^{T-1} x_j^2 + \ldots \sum_{j=1}^{n} a_{ij}^1 x_j^T \leq b_i^T$$

$$x_j^T \geq 0$$

$$\text{for } j = 1, 2, \ldots, n$$
$$i = 1, 2, \ldots, m$$
$$t = 1, 2, \ldots, T$$

Where c_j^t = the contribution per unit of activity x_j initiated in period t

x_j^t is the level at which activity x_j is initiated in year t

a_{ij}^t is the per unit requirement of activity x_j for resource b_i in period t

b_i^t is the supply of resource i in period t.

The use of I.L.P. models in agricultural studies has been described by Swanson [22], Loftsgard and Heady [12], Candler [4], Candler and Boehlje [5], Olsson [14], Boussard [3], Throsby [23], Colyer [7] and others. The use of the model has been demonstrated by Stewart and Thornton [21], Rae [18], Abalu [1], Jensen [11], Chien and Bradford [9], Willis and Hanlon [24], amongst others.

Early applications of the I.L.P. model were generally designed to maximise the present value of future incomes over some planning period. In commenting on the study by Loftsgard and Heady, Candler [4] suggested that it would be equivalent, but simpler to build a model that would maximise income at the end of the planning period. The inter-temporal model presented in this paper is based upon that proposed by Candler [4] and described by Rae [17] with an objective of maximising a weighted sum of several individual goals such as the sum of after tax cash and the value of assets owned by the firm at the end of the planning horizon.

2.2 Structure of the Model

The general structure of the I.L.P. model is shown in schematic form in figure 2.1. By referring to figure 2.1 it can be seen that the model consists of two major sets of activities:

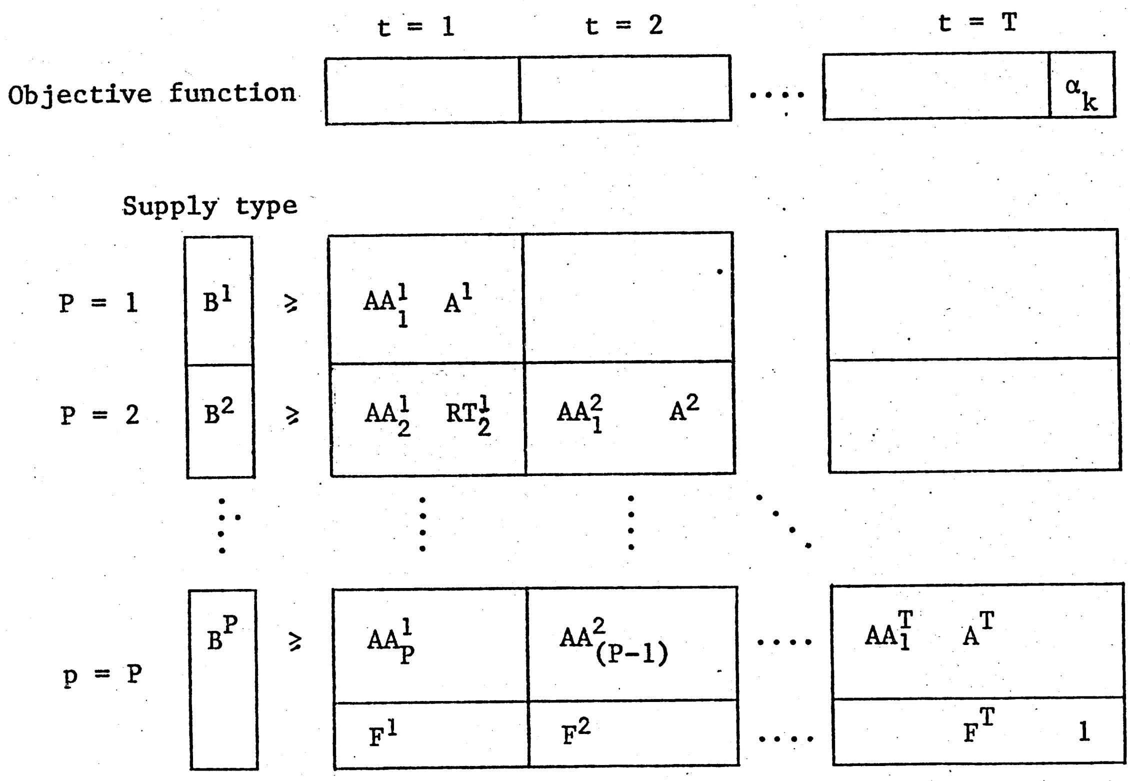
(a) A set of activities (A) to model the existing orchard activities and cash flows; and

(b) A set of "adjustment" activities (AA) to allow for the adoption of new enterprises.

As the entire matrix consisted of over 500 row vectors and 1200 column vectors it is not possible to show the entire model in this report. However, a simplified illustration of the submatrix concerned with the final year of the planning horizon is presented in Appendix A.

The flow of cash through the model, the objective function and the length of the planning horizon are several issues of particular importance to an understanding of the model. Therefore a discussion of these features will precede an examination of the various activities and constraints included in the model.

Figure 2.1 The General Structure of the Intertemporal Model



Where AA_p^t = submatrices of coefficients for activities initiated in year t, with a resource requirement in period p

A^t = sub matrices of coefficients for existing activities and transactions within year t

RT_p^t = submatrices of coefficients for transfer of resources from year t to period p

F^t = vector of coefficients of final asset values of activities initiated in year t

B^t = vector of resources and restrictions in period p

αk = a vector of objective function coefficients corresponding to the weights attached to the final q goals

for $t = 1, 2, \ldots, T$

$k = 1, 2, \ldots, q$

$p = 1, 2, \ldots, P$

$P = T$.

2.2.1 Cash flow in the model

Figure 2.2 summarises the flow of cash within the model. Cash transferred from the end of the previous year is made available for use at the start of year t. From this amount the model deducts the fixed costs such as mortgage and interest repayments, fixed insurance costs and a specified amount for personal consumption to cover such expenses as food and clothing. Having deducted the fixed costs the variable costs of production for the year t are calculated. Borrowing on mortgage or overdraft rates is permitted to overcome cash infeasibilities should cash be limiting. Under circumstances of cash surplus, the cash not required for farm production or reinvestment may be invested off the farm at a specified interest rate.

At the end of the year the tax deductible costs incurred during the year are summed, i.e. the portion of fixed costs that were tax deductible, the variable production costs and the interest paid on monies borrowed. The total tax deductions are then subtracted from the total income earned during the year to arrive at the taxable income for year t. The amount of tax payable on the taxable income is calculated and deducted from the taxable income to give the after-tax cash. Appropriate adjustments are then made for the principal components of monies either borrowed in year t or invested off the farm. The residual then gives the amount of cash available at the start of year t + 1.

2.2.2 The objective function and the length of the planning horizon

The I.L.P. model made use of an objective function which maximised the weighted sum of individual goals at the end of the planning period. As the "well-being" of farm families can be measured as some combination of annual income and asset accumulation [2/] it was decided that a suitable objective to maximise would be the sum of after tax cash and the value of assets [3/] at the end of the planning horizon subject to a given level of personal drawings each year. Accordingly, only two non-zero values

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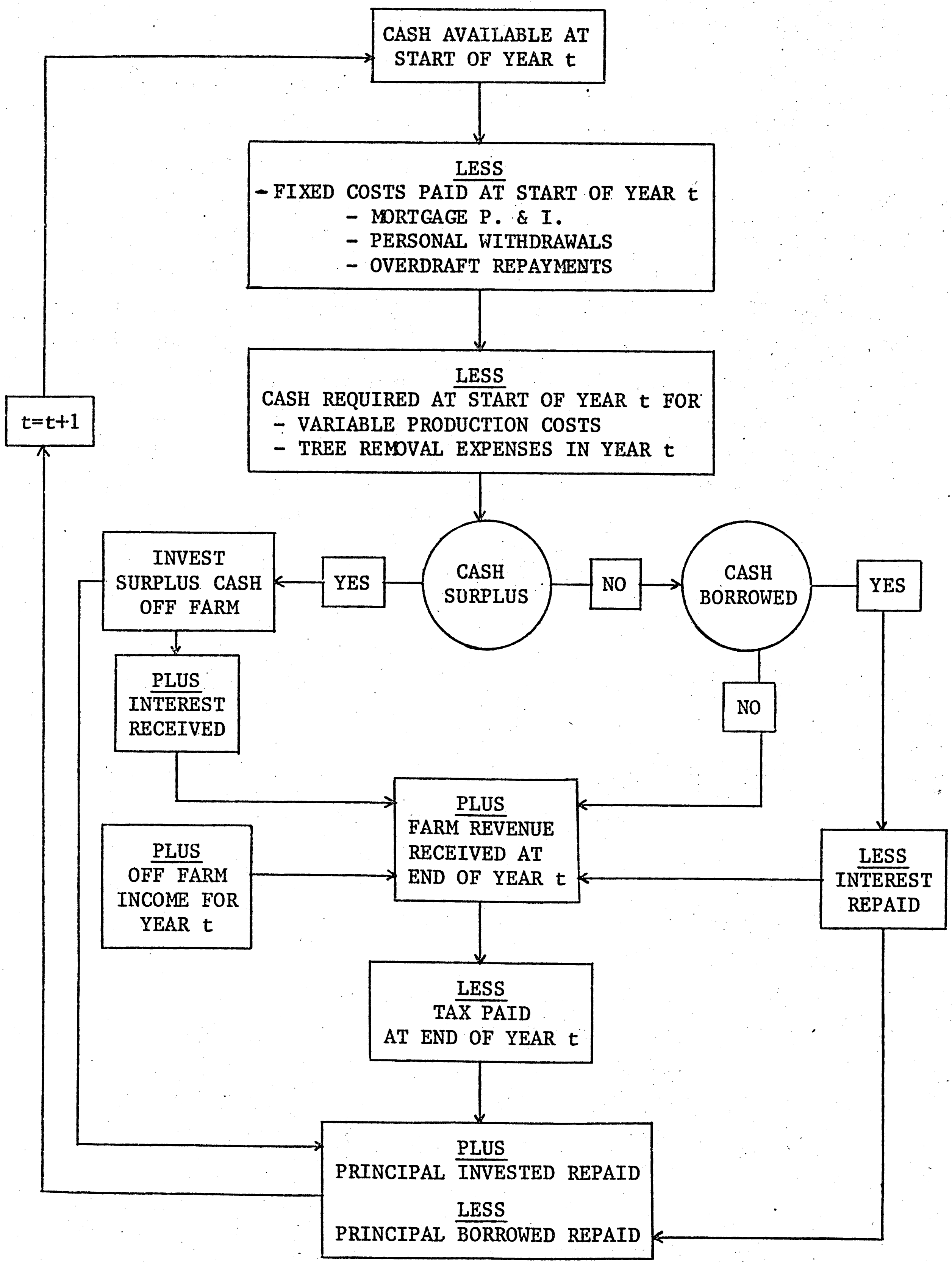
2/ See [11]

3/ The value of Final Assets was defined as the present value of future net revenues of perennial crops, in existence at the end of the planning horizon, discounted from infinity to the end of the planning horizon, with crop replacement at the optimum time.

Figure 2.2 Cash Flow in the Intertemporal Model



appear in the objective function,4/ these being the weights attached to the final cash and final assets activities. A graphical representation of this two dimentional objective function is presented in Fig.2.3.

In considering the length of the planning horizon it was recognised that as the average age of pip fruit producers on the Moutere Hills was 40 years (Rae et.al. [18] a maximum planning horizon of 20 years would meet the needs of these decision makers, even though this period would probably fall short of the time required to reach a new equilibrium situation. Accordingly, a model with such a planning horizon was constructed and solved for a bench mark situation. However, the model became too large and expensive to use when augmented with the various adjustment activities. Therefore, the planning horizon in the model developed was reduced to a ten year period. This was regarded as a compromise between two requirements:

(a) a period long enough to allow the study of the adjustment process;

and

(b) a period which is sufficiently short to allow the model to be handled without too much difficulty.

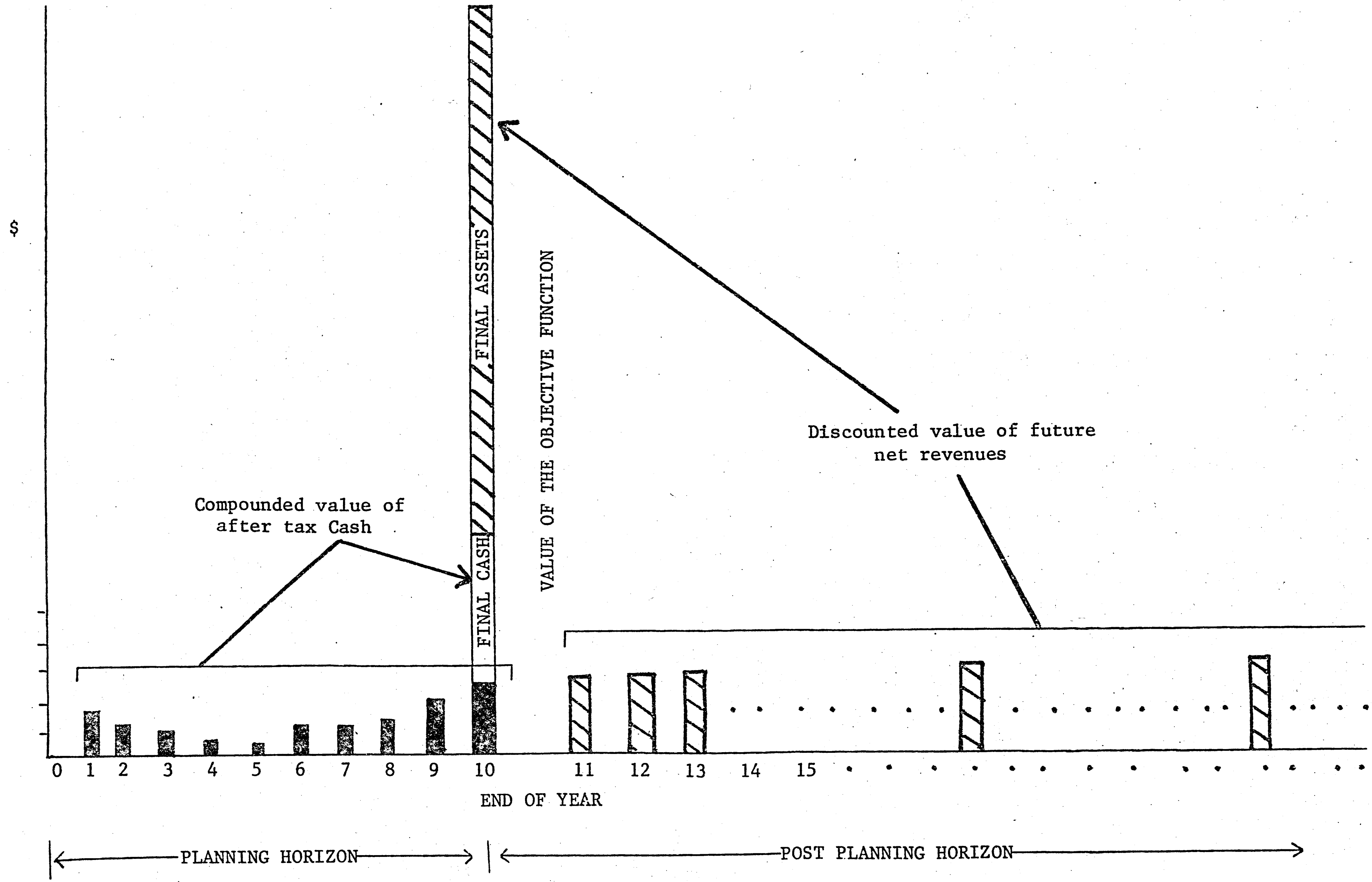
2.2.3 The constraints

The major constraints included in the model may be grouped as follows:

(i) existing tree number constraints
(ii) land constraints
(iii) labour constraints
(iv) financial constraints
(v) variety limitation constraints
(vi) accounting constraints
(vii) final cash and asset constraints,

4/ The inclusion of one final cash activity did not, however, allow for the possibility of a cash deficit at the end of the planning period (by the non-negativity assumption). Thus the objective function was later augmented with the inclusion of a final cash deficit activity which allowed for the possibility of cash deficits which occurred when the planning horizon was reduced from 20 to 10 years.

Fig. 2.3 Components of the Objective function



(i) Existing tree number constraints.

A set of constraints corresponding to the existing tree activities were formulated in order to limit reworking and interplanting to no more than the initial tree number.

(ii) The land constraints.

A single constraint in each year of the planning period constrained total land utilisation to no more than the area available.

(iii) Labour constraints.

Two sets of labour constraints were included in the formulation of the model. The year was first divided into three periods to reflect the major periods of orchard activity, i.e.

(a) the dormant period : June - August
(b) the growing season : September - December
(c) the harvest period : January - May.

Then, in view of the importance of labour employment throughout the harvest, this period was further subdivided into nine fortnightly periods in order to provide a second set of constraints that would determine labour requirements and picking costs throughout the harvest period.

(iv) Financial constraints.

Three financial constraints were set up to facilitate cash flow accounting and the determination of taxation. The first cash constraint limits total expenditure to no more than the cash available at the beginning of the year plus borrowings. The second restraint allows the amount of tax payable in a year to be determined. The final cash restraint permits the income earned to be divided into:

(a) a proportion covered by tax deductible costs, i.e. taxfree and therefore income which is available at the start of year t + 1 (as costs are all paid at the start of each year);

(b) a proportion to be taxed (the after tax cash component is then also made available in year t + 1).

(v) Variety limitation constraints.

In order to overcome the problem of labour bottlenecks at harvest time, a number of varieties of perennial crops are usually grown to provide an even supply of fruit throughout the harvest period. To constrain the model from choosing the most profitable variety for orchard reconstruction a set of constraints were included to restrain the proportion of the various varieties of perennial crops grown to a maximum percentage of total tree numbers.[5/]

(vi) Accounting constraints.

"Non computational" constraints may be used for accounting purposes. The I.L.P. model used such a constraint to determine the total quantity of fruit harvested each year.

(bii) Final asset and cash constraints.

The final asset and cash constraints appear only once, in the final year of the model. These constraints were used to determine:

(a) the final asset value of all perennial plantings at the end of the planning period;

and

(b) the final after tax cash position at the end of the planning period.

The resultant values were then transferred to the objective function of the model.

2.2.4 The activities

The activities included in the I.L.P. matrix and repeated in each year of the planning horizon can be divided into the following categories:

5/ Constraining varieties on the basis of tree numbers as opposed to the quantity of fruit harvested in each fortnightly sub period of the model is preferred as the former method takes into account the problem of harvest periods beyond the planning horizon. Limiting varieties on the basis of fruit production on the other hand, would not necessarily ensure a desired distribution of fruit throughout the harvest period as new plantings may not come into full production during the planning horizon.

(i) existing orchard plantings
(ii) tree removal activities
(iii) new plantings of perennials
(iv) interplanting and reworking activities
(v) annual activities
(vi) activities to hire labour
(vii) financial and taxation activities
(viii) final cash and asset transfer activities.

(i) Existing orchard plantings.

The existing plantings of perennial crops were aggregated into 30 activities on the basis of variety, age and density of planting. The added detail to be derived from such a grouping as opposed to a grouping on the basis of variety alone was intended in order to answer questions relating to the optimum replacement of selected age groups of trees.

(ii) Tree removal activities.

Because of the cost and/or labour time involved in the removal of existing trees, a set of tree removal activities were incorporated. While these activities may appear superfluous in reconciling tree numbers their inclusion was intended to allow greater accuracy in the estimation of labour times and costs, both of which are seen as critical factors in orchard production.

(iii) New plantings of perennials.

To facilitate the restructing of orchards a number of activities were included to allow for the planting of new or additional varieties of perennial crops. In order to limit the size of the matrix only the most likely candidates were included, selection being made on the basis of the net present value of the variety. (See page 24).

(iv) Interplanting and reworking activities.

A second set of orchard adjustment activities permitted existing trees the option of being interplanted or reworked to other varieties. As existing tree activity could be reworked or interplanting with any one of a number of varieties in any year of the planning horizon, it was again necessary to restrict the number of options available to the most likely candidates in order to limit matrix size.[6/]

(v) Annual activities.

The inclusion of a number of activities such as off farm work and cattle fattening on an annual basis without provision for herd replacement etc., provided a further set of adjustment activities.

(vi) Activities to hire labour.

Two sets of activities were included to provide for additional labour to be hired for seasonal work and/or fruit picking. Differential rates of pay were invoked for the two classes of labour which supplemented the owner operator's contribution.

(vii) Financial and taxation activities.

To facilitate the cash flow accounting previously described, the following activities were repeated in each year of the I.L.P. model:

- cash borrowing on either mortgage or overdraft rates;
- cash saving in the form of off-farm investment;
- taxation activities to calculate tax payable;
- a tax deduction transfer activity.

Since all tax deductible expenditures must be substracted from income earned before taxation is calculated the tax deductions transfer activity allows a sum equal to the tax deductible expenditures of that year to be substracted from the pre tax income and transferred to the supply of cash available at the beginning of the next year.

(viii) Final cash and assets transfer activities.

This set of activities, unlike other activities, appears only once in the final year and acts to transfer the value of final assets and cash to the objective function.

6/ For example, 30 existing tree activities given the option of being interplanted or reworked to any 6 new varieties in any year of a 10 year planning horizon implies 3600 activities.

2.3 The Data Used in the Model

2.3.1 Selection of the representative orchard

The use of representative farms in policy analysis has been described by Day [8], Carter [6], Plaxico and Tweenten [16], Sheehy and McAlexander [20], Sharples [19] and others. While representative farms have been criticised, first for their inability to portray intangible factors such as management, and secondly in that their static nature only allows farms to remain representative within given levels of technology (Barnard [2]), the seriousness of these criticisms depends on the use that is made of such farms, i.e. whether conclusions are to be extrapolated to a local, regional or national point of view.

In this study we are interested in a relatively homogeneous group of pip fruit producers, i.e. those pip fruit growers on the Moutere Hills who are either currently or potentially exhibiting symptoms which have resulted from a failure to adjust. Also, as any conclusions drawn from this study are intended for this select group of producers alone, a representative farm approach was seen as being the most suitable way of obtaining much of the data required for the I.L.P. model.

By combining various aspects of the approaches described by McClatchy and Campbell [13] and El Adeemy and MacArthur [10], a procedure was derived to facilitate the quantitative selection of a representative orchard.

The age structure and variety composition of orchards are two major factors which reveal the seriousness of the on farm adjustment problem, these criteria were therefore used to determine a sub-sample of problem growers on the Moutere Hills.[7/] This sub-sample, consisting of those growers with a low percentage of high valued varieties (i.e. Granny Smith, Red Delicious, Cox and Gala) and more than 60 percent of all fruit trees greater than five years of age, was then used as a sampling frame from which to select the representative problem orchard.

7/ The sub-sample was derived from sample growers involved in a survey of the New Zealand Pip Fruit Industry, see Rae et al. [18]

Using the data obtained in the N.Z. Pip Fruit Industry Survey, a number of frequency distributions of important characteristics were constructed for the Mapua sub-sample. Appendix Table B1 shows the distribution of values occurring on these farms for some selected features which were considered important in this type of farming. The modal situation was then identified by inspection.

To isolate the farm which most nearly approached the "modal farm" the deviation of each farm from the modal situation was calculated. The farm with the lowest aggregate deviation was then selected as the representative farm. Appendix Table B2 lists the various characteristics considered in the selection of the representative orchard and compares the selected orchard with the sub-sample mean and modal values.

The grower thus selected was subsequently contacted. Upon agreeing to cooperate in the study a series of three interviews was conducted during which an extensive amount of farm data was collected. This data was then used to derive matrix input-output coefficients, the derivation of which will be described in the next section.

Because of the homogeneity of the Moutere Hills orchards and the particular resource allocation of the selected representative orchard it was decided to base this study on one actual representative farm as opposed to a synthetic representative farm. The representative orchards variety composition shown in Appendix Table B3 serves to further illustrate the suitability of the selected orchard used in this study.

2.3.2 Derivation of matrix coefficients

In this section we outline the procedures which were adopted to derive some of the matrix coefficients from basic farm data. Because of the size and complexity of the model it is not possible to cover the derivations of all input coefficients in this account. However, a sub-set of the more critical coefficients has been selected for examination.

These include:

(a) yields;
(b) pre-tax cash receipts;
(c) seasonal labour requirements for all activities other than fruit harvesting;
(d) labour requirements for harvesting;
(e) cash requirements;
(f) asset values of perennial crops.

(a) Yields

Projections of perennial crop yields were required in order to determine variable costs of production, such as picking costs and transport costs, total revenue and final asset values of the various perennial crop activities. As such it was necessary to estimate the annual yield for each perennial crop activity included in the model. In order to do this the annual yield of pip fruit was assumed to consist of two major components:

(1) a component due to tree age; and
(2) a component due to an increase in productivity.

The contribution of each component was estimated and summed to arrive at an annual expected yield.

(1) Yield due to tree age

In order to estimate the yield due to tree age, use was made of the cross sectional data collected in the N.Z. Pip Fruit Industry Survey. To estimate the yield of pip fruit through time the following yield projection model was formulated:

$$\frac{Y_i}{N_i} = \sum_{j=1}^{n} \hat{\beta}_{ij} \frac{X_{ij}}{N_i} \qquad (2.1)$$

where Y_i = total orchard yield of variety i

X_{ij} = number of trees of variety i in age group j

N_i = total number of trees of variety i in the orchard

$\hat{\beta}_{ij}$ = average yield per tree for trees of variety i in age group j. Four age groups were used, these being 0-5 years, 6-15 years, 16-50 years, greater than 50 years.

(2) Yield due to an increase in productivity.

The second component affecting yield through time is the effect of changing productivity. Time series data supplied by the Ministry of Agriculture and Fisheries was used to determine an annual rate of growth in productivity for apple and pear production in Mapua.

The yield increase in productivity of apples and pears was calculated from the equation:

$$\frac{Y}{BT} = \hat{\beta}_o + \hat{\beta}_1 t + \hat{\beta}_2 D$$

where $\frac{Y}{BT}$ = yield per bearing tree

t = a time trend variable

D = a dummy variable to recognise the biennial bearing habits of apple trees.

Using these equations the annual rate of growth in productivity was then estimated as

Apples 1.6 percent per year;
Pears 0 percent per year.

These rates were then combined with the estimated annual yields to produce a final annual yield estimate for each of the various varieties of pip fruit, i.e. the expected yield/tree/year that could be expected for each variety between 1976 and 2041 (assuming a productive life of 65 years).

(b) Pre-tax cash receipts.

In order to derive the pre-tax cash income it is first necessary to establish annual prices received. The price growers receive for pip fruit is determined by:

(1) the size distribution of the crop, which is in turn determined by (a) tree age and (b) the effect of various managerial factors; and

(2) the percentage of fruit destined for export, local market and processing.

From the growers' records and data obtained from the Nelson Co-operative Packhouse, the size distribution and export pack-out were determined for 1974 and 1975. Then based on the 1976 New Zealand Apple and Pear Board's Price List, an appropriately weighted, average price was determined for each variety of pip fruit. This average price was then further modified to reflect the changing size distribution of a pip fruit crop through time. Although a continuous price function would have been desirable for simplicity, a price differential was applied to the following age groups of pip fruit trees:

(1) less than 8 years of age to reflect the ban of export fruit from trees of this age group;
(2) 8 - 45 years; and
(3) greater than 45 years to reflect the small sized fruit from older trees.

The relevant pre-tax cash receipt was then given by:

$$R^t_{pj} = P^t_j \times Y^t_{pj} \quad \text{8/}$$

where R^t_{pj} = the total revenue received in year t by the jth activity, initiated in year p

P^t_j = the price for the jth activity in year t

Y^t_{pj} = the yield in year t for the jth activity initiated in year p.

8/ For the purpose of deriving various matrix coefficients the index notation should be interpreted as follows:
t - each year of the planning horizon
j - each productive activity
p - the year in which an activity is initiated.

(c) Seasonal labour requirements.

Seasonal labour requirements were determined as follows:

(a) Winter labour:

$$WL_j^t = PT_j^t + TT_j^t$$

where WL = the requirement for winter labour
PT = the time required for pruning
TT = the time required for training.

(b) Growing season labour:

$$GL_j^t = TT_j^t + S_j^t + T_j^t + C_j^t + M_j^t + F_j^t + WS_j^t$$

where GL = the requirement for growing season labour
TT = the requirement for tree training
S = the requirement for tree spraying
T = the requirement for fruit thinning
C = the requirement for cultivation
M = the requirement for mowing
F = the requirement for fertiliser application
WS = the requirement for weed spraying.

(c) Harvest season labour:

$$HL_j^t = C_j^t + M_j^t + T_j^t + P_j^t + WS_j^t + S_j^t + CT_j^t$$

where HL = the requirement for harvest season labour
P = the requirement to prop and tie trees
CT = $(0.0985 \times Y_j^t)$ = the time required to transport Y bushels of fruit to the co-operative packhouse.

(d) Determination of picking time.

In order to meet export requirements pip fruit are picked throughout the harvest period as shown in figure 2.4. To determine the demand for harvest labour, estimates of average picking rates for all varieties of pip fruit at various ages were determined from information supplied by the grower. This information was then combined with the proportion of the various varieties that were harvested in each of nine fortnightly harvest season periods. These proportions were calculated on a variety basis from the 1973 and 1974 weekly receipts of the Apple and Pear Board's depot at Mapua.

The number of hours required in the kth fortnightly period, for the jth perennial crop activity in the tth year of the planning horizon was then given by

$$PL_{kj}^{t} = \frac{PR_{kj} \times YD_{j}^{t}}{PT_{j}}$$

where PL = the number of hours required per fortnight

PR = proportion of each variety harvested in each fortnight

YD = the expected yield of each variety

PT = the average picking rate.

(e) Cash.

The cash requirement coefficients were determined as the sum of all cash costs less the cost of labour, as this cost was determined endogenously elsewhere, i.e.

$$CR_{j}^{t} = TR_{j}^{t} + TK_{j}^{t} + SC_{j}^{t} + FC_{j}^{t}$$

where CR = the cash requirement

TR = the number of tractor hours involved in each operation (e.g. spraying mowing etc.) in each year; plus the number of truck hours involved in each operation (e.g. fruit cartage) in each year; multiplied by the appropriate truck running cost/hour for the relevant year.

SC = the cost of the qth spray applied to each variety for q, herbicide, pesticide and thinning sprays.

FC = cost of fertilizer.

(f) Asset values of perennial crops.

Perennial crops in existence at the end of the planning horizon were assigned asset values equal to the present value of future net revenues

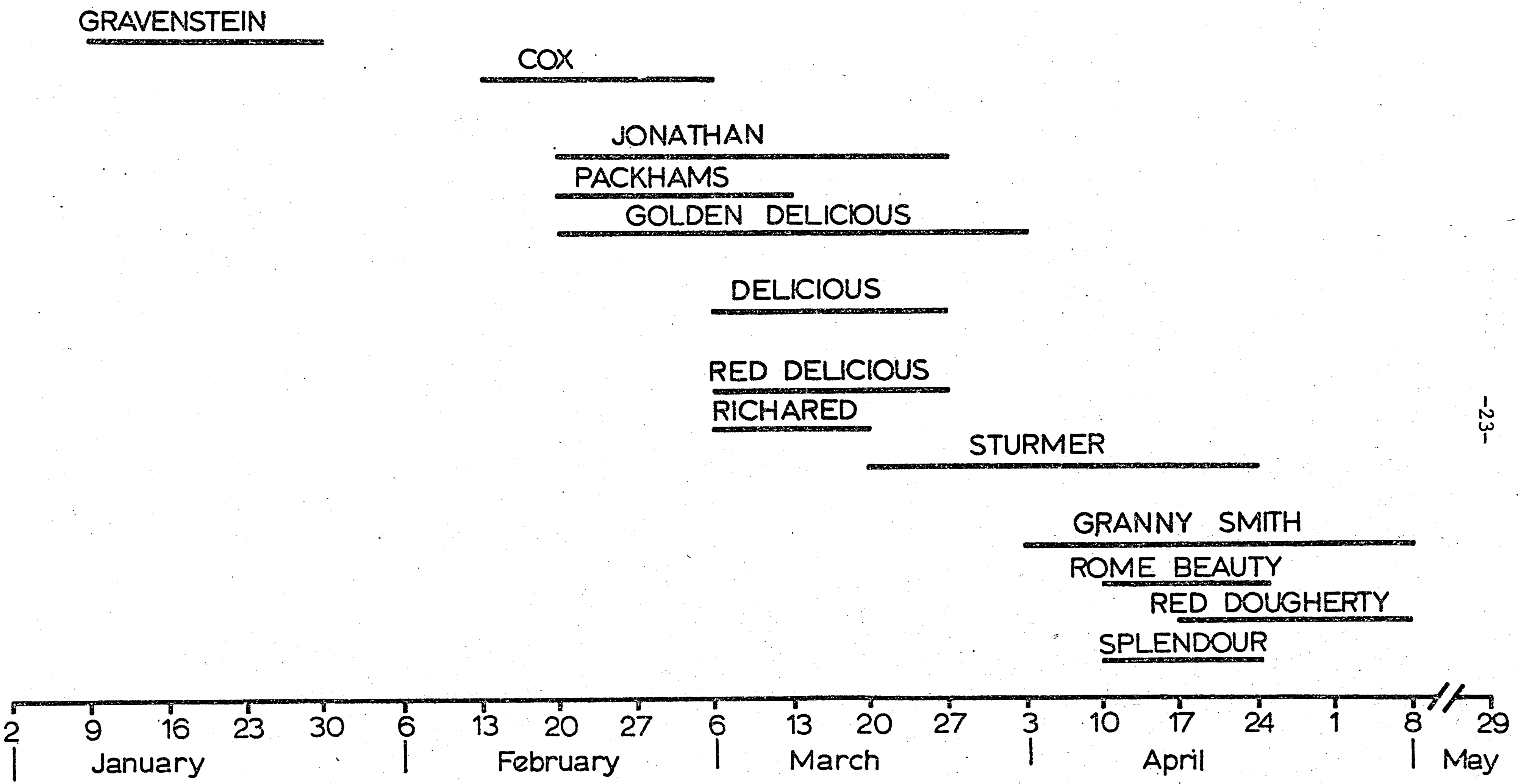


Figure 2.4 Picking Times for Pip Fruit

discounted from infinity with crop replacement at the optimum time.

The optimum replacement time for each perennial crop activity was calculated as the year in which the annual net revenue (marginal net revenue) equalled the amortized present value of net revenues from that activity.

The amortized present value over any production cycle of t years was given by:

$$A = \left[\sum_{t=1}^{n} \frac{NR_j^t}{(1+i)^t} \right] \cdot \left[\frac{i(1+i)^t}{(1+i)^t - 1} \right]$$

where NR_j^t = Net revenue of the jth activity in the tth year

i = discount interest rate.

Asset values for each activity were then derived from the following equation:

$$AV_j^t = \frac{NRm+1}{(1+i)} + \frac{NRm+2}{(1+i)^2} + \ldots, \frac{NRm+m}{(1+i)^m} + \frac{\frac{A*}{i}}{(1+i)^{n+1}}$$

where AV_j^t = the asset value of activity j, initiated in year t

NR_m = net revenue of the activity in year m

m = age of the tree at the end of the planning horizon

m+m = optimum replacement age

A* = maximum amortized present value of activity j.

3.0 A Linear Programming Analysis of Orchard Farm Adjustment

3.1 Procedure

In order to use the results of any economic model for policy recommendations it is mandatory that the research method contain both internal and external validity. In this study the external validity of the experimental design has already been covered in that part of section 2 which dealt with the selection of the representative farm. Internal validity of the research method was achieved by subjective validation of the I.L.P. model in addition to the use of benchmark models. A benchmark model, as opposed to an adjustment model is a variant of the I.L.P. model in which the adjustment activities have been omitted. As such the benchmark model indicates the result of orchardists maintaining the status quo, and therefore may be considered as analgous, with respect to experimental design, to the "control plot" used by scientists in field trials.

Because a direct comparison could not be made between the performance of the real system and that produced by the model, the approach recommended by Wright [25] was used to validate the model. In this approach subjective validation is used, the model being considered validated if it would be used by the decision maker as a basis for decision making. Accordingly, the results obtained from the I.L.P. model were discussed with the representative grower and various extension personnel. These discussions, together with a comparison between the actual farm situation and the results, indicated that the model could be used with sufficient confidence to consider the model validated.

Having constructed and validated the model, experimentation proceeded with the aim of producing a set of results which would give an insight into optimal adjustment strategies for Moutere Hill pip fruit producers. The model was initially solved by assigning equal weights to the value of final assets and the after tax cash coefficients in the objective function. The results that were subsequently obtained from the adjustment model (plan A1) will now be discussed and compared with those obtained from the corresponding benchmark model (plan B1).

3.2 Results - Plans A1 and B1

3.2.1 Structural adjustment[1/]

The structural adjustment indicated in plan A1 is summarised in table 3.1. This optimum adjustment plan specified that unprofitable varieties such as Rome Beauty, Jonathan, Gravenstein, Delicious and Golden Delicious are to be removed immediately. Non-bearing and old Sturmers (greater than 50 years of age) are also to be removed immediately, bearing Sturmer trees (between the age of 5 and 50 years) are to be maintained until 1982/83 at which time they should gradually be removed over a two year period. Splendour, Red Dougherty and old Cox trees are to be kept for eight years in order to provide cash during the early years of the adjustment period. However, these varieties are also to be removed in the final years of the planning horizon so that they may be replaced by new Cox and Granny Smith trees. Over the entire planning horizon 47 percent of 2060 of the initial

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1/ As the benchmark model did not include any adjustment activities such as tree removal, tree planting or reworking of orchard trees the number of trees in plan B1 remained constant throughout the planning horizon.

Table 3.1 Optimum Orchard Adjustment Programme: Plan A1

Variety	Age at 30 June 1976	Effective spacing (metre)	Interplanted or reworked	Initial tree numbers	Additions and removals						Final tree no. 1985/86
					1976/77	1980/81	1981/82	1982/83	1983/84	1984/85	
1. EXISTING TREES											
Granny Smith	1	4.8 x 4.8		36							36
Granny Smith	2	4.8 x 4.8	R/W	166							166
Granny Smith	4	4.8 x 2.7		80							80
Granny Smith	10	5.5 x 5.5		136							136
Granny Smith	2	5.5 x 5.5	I/P	210							210
Granny Smith	6	5.5 x 5.5	I/P	106							106
Cox	3	4.8 x 4.8		260							260
Cox	9	5.5 x 5.5		269							269
Cox	54	5.5 x 5.5		79					R 79		
Cox	1	5.5 x 5.5	I/P	116							116
Red Delicious	1	5.5 x 3.6		267							267
Red Delicious	6	4.8 x 3.6		94							94
Red Delicious	3	5.5 x 5.5	I/P	75							75
Richared	6	4.8 x 4.8	R/W	82							82
Gala	3	4.8 x 3.6		159							159
Golden Delicious	5	4.8 x 4.8		71	R 71						
Golden Delicious	6	5.5 x 5.5		210	R 210						
Golden Delicious	55	5.5 x 5.5		51	R 51						
Delicious	58	5.5 x 5.5		280	R 280						

NOTE: P = Plant; R = Remove; I/P = Interplant; R/W = Rework or graft

Cont./...

Table 3.1 Optimum Orchard Adjustment Programme: Plan A1 - <u>continued</u>

Variety	Age at 30 June 1976	Effective spacing (metre)	Interplanted or reworked	Initial tree numbers	Additions and removals						Final tree no. 1985/86
					1976/77	1980/81	1981/82	1982/83	1983/84	1984/85	
Sturmer	3	4.8 x 4.8		42	R 42						
Sturmer	15	5.5 x 5.5		199				R 89	R 110		
Sturmer	54	5.5 x 5.5		317	R 317						
Red Dougherty	9	4.8 x 4.8		152						R 152	
Gravenstein	50	4.8 x 4.8		229	R 229						
Jonathan	55	4.8 x 4.8		263	R 263						
Rome Beauty	30	4.8 x 4.8		49	R 49						
Splendour	5	4.8 x 4.8		118					R 14	R 104	
Packhams	3	4.8 x 4.8	R/W	110							110
Packhams	8	4.8 x 4.8		53							53
Winter Cole	8	4.8 x 4.8		52							52
2. <u>NEW TREES</u>											
Granny Smith					I/P 477						678(P201)
Cox											P 1246
Red Delicious							P 620	P 1042			P 1662
Gala									P 788	P 43	831
Packhams					P 1201	P 460					1661
Winter Cole										P 831	831
TOTAL TREE NUMBERS				4331	4497	4957	5577	6530	7115	7733	9180

<u>NOTE</u>: P = Plant; R = Remove; I/P = Interplant; R/W = Rework or graft.

4331 trees should be removed and be replaced by more profitable varieties.

In conjunction with the removal programme a comprehensive planting programme was also initiated in 1976/77. Four hundred and seventy seven Granny Smith trees are to be interplanted between existing orchard trees. In addition, the planting of 1201 Packham trees is also specified. Further plantings of Packhams are then made four years later in 1980/81 with plantings of Red Delicious, Gala, Winter Cole, Cox and Granny Smith following as shown in table 3.1. In total 6909 new trees should be planted over the planning horizon bringing the final tree number to 9180 trees in 1985/86.

The structural adjustment suggested by plan A1 will reduce the number of different varieties grown from 15 to 7 and shift the age distribution of trees to the younger age groups. Table 3.2 gives the age distribution by variety of orchard trees in the final year of the planning horizon. The fact that 57 percent of the trees are of non-bearing age in 1985/86 has important implications for future cash flow as the major benefits which might be expected to accrue from this adjustment programme will still remain to be realized after the planning horizon. This point is discussed in greater detail on page 32.

Table 3.2 Age Distribution of Trees in 1985/86: Plan A1

Variety	Age of trees				Total
	0 - 5	6 - 20	21 - 50	More than 50	
Granny Smith	201	1 075	136		1 412
Cox	1 246	645			1 891
Red Delicious	1 662	436			2 098
Richared		82			82
Gala	831	159			990
Packhams	460	1 364			1 824
Winter Cole	831	52			883
TOTAL	5 231	3 813	136	-	9 180

3.2.2 Expected yields

The high percentage of young or non-bearing trees in the adjustment plan is also reflected in the difference between the expected total yields of pip fruit from plan A1 when compared with the expected yields from plan B1. (See table 3.3 below).

Table 3.3 Pip Fruit Production: Plans A1, B1 (bushels)

Year	Plan A1	Plan B1
1976/77	11 555	17 473
1977/78	13 223	19 126
1978/79	13 803	19 722
1979/80	15 589	21 301
1980/81	17 197	22 997
1981/82	21 494	25 112
1982/83	24 191	27 252
1983/84	21 293	27 927
1984/85	20 629	28 062
1985/86	18 697	29 394

These differences in yields will also help to explain the differences in labour requirements, costs and revenues for the years 1976/77 to 1985/86. It is in this direction that attention is now focussed.

3.2.3 Financial implications of adjustment

In order to achieve the orchard restructuring programme outlined above it would be necessary to obtain sufficient finance to permit personal consumption of $3000 per year, allow the existing orchard to be managed and permit the development plan to be executed. Table 3.4 summarises the financial results of both plans A1 and B1. The cumulative cash balance which is given may be viewed as the end of year bank balance.

Table 3.4 Cumulative Cash Balance: Plans A1, B1 ($)

Year	Plan B1	Plan A1
1975/76	7 000	7 000
1976/77	131	-1 715
1977/78	-5 429	-6 185
1978/79	-9 939	-9 915
1979/80	-17 456	-16 625
1980/81	-17 240	-17 668
1981/82	-15 158	-15 584
1982/83	-11 800	-13 858
1983/84	-7 595	-12 289
1984/85	-2 306	-10 359
1985/86	3 949	-10 701
Present value of final cash balance (7%)	2 007	-5 439
Present value of final assets (7%)	170 309	468 223
Present value of objective function (7%)	172 316	462 784

The negative cumulative cash balances shown for plan B1 reflect the need for borrowing in early years while the young trees planted prior to the planning horizon slowly come into bearing. The positive cash balance in 1985/86 indicates the reduced need for loan finance as orchard trees reach full bearing. The cumulative cash balance for plan A1 on the other hand, reflects even heavier borrowing that must be incurred in order to finance the various adjustment activities.

In both plans A1 and B1 the final assets and final cash coefficients of the objective function were assigned equal values. The value of the objective function was then given as the sum of the after tax cash at the end of the planning horizon and the value of future income discounted from infinity to 1985/86. In table 3.3 both components of the objective function and the value of the objective function are presented in present value terms (i.e. with respect to 1976/77). The interpretation of the value of the objective function ~~should be clear. It is~~ was described on page 11 as a comprehensive measure of the profitability of ~~each~~ an orchard plan viewed with respect to an equilibrium in which orchard trees are replaced at the optimum replacement age.

Although the present value of final cash is greater for plan B1 than plan A1 the real value of the adjustment plan accrues in the years following the planning horizon. This is shown by the 274 percent increase in the present value of final assets of plan A1 over plan B1. In order to show the pattern of income and expenditure required to generate the cash balances shown in table 3.4 a summary cash flow statement is presented in tables 3.5 and 3.6 for plans B1 and A1 respectively.

The expected cash flow is presented in two parts. The entries which appear above the dashed line occur at the beginning of the year and those below the dashed line occur at the end of the year. The manager, who therefore opts to maintain his orchard in its current state and not adopt an adjustment programme, could expect to find that $14,045 would need to be borrowed in the first year of the planning horizon to supplement the initial cash balance of $7000. The loan of $14,045 would be just sufficient to cover personal drawings and farm costs for the year. At the end of the year repayments of interest and principal amounting to $15,169 when subtracted from the gross revenue earned would leave a cash balance of $131 in the bank. This amount must then be supplemented by a further loan of $21,629 at the start of the second year in order to cover the cost of expenses incurred at the start of the 1977/78 year. In this way it is possible to trace out the pattern of cash flow throughout the planning period. The manager who adopts plan B1 can therefore expect to have $3949 in the bank on 30th June 1985 while the manager who adopts the optimum adjustment plan can expect to have a deficit bank balance of -$10,701.

The annual cash balances that can be expected from plans A1 and B1 are shown in figure 3.1. Both plans show that annual cash deficits can be expected to occur for the first five years of the planning horizon. After 1980/81 plan B1 shows that cash surpluses are likely to accrue annually, while the first positive annual cash balance for plan A1 is likely to occur in 1982/83. The more variable pattern of annual cash balances in plan A1

Table 3.5 Cash Flow Summary: Plan B1

Cash flow items	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Opening cash balance	7 000	131	-5 429	-9 939	-17 456	-17 240	-15 158	-11 800	-7 595	-2 306
plus Loan 1 received	14 045	21 629	27 552	36 719	38 733	39 212	38 295	35 331	31 271	26 574
less Personal drawings	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000
less Cash fixed costs	4 760	4 760	4 760	10 760[a)]	4 760	4 760	4 760	4 760	4 760	4 760
less Cash farm costs	13 285	14 000	14 363	13 020	13 516	14 212	15 377	15 771	15 916	16 509
plus Gross farm revenue	15 300	17 930	19 817	22 200	24 963	28 480	32 054	34 072	36 251	38 608
less Loan 1 repaid + interest	15 169	23 359	29 756	39 656	41 832	42 349	41 358	38 158	33 773	28 700
less Tax paid					371	1 289	2 496	3 509	4 784	5 959
equals Cumulative cash balance	131	-5 429	-9 939	-17 456	-17 240	-15 158	-11 800	-7 595	-2 306	3 949

a) Incorporates the net balance resulting from the replacement of a tractor.

Table 3.6 Cash Flow Summary: Plan A1

Cash flow items	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Opening cash balance	7 000	-1 715	-6 185	-9 915	-16 625	-17 668	-15 584	-13 858	-12 289	-10 359
plus Loan 1 received	18 280	24 805	29 845	38 314	40 000	40 000	40 000	40 000	40 000	40 000
plus Loan 2 received					1 367	3 000	3 000	3 000	3 000	3 000
less Personal drawings	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000
less Cash fixed costs	4 760	4 760	4 760	4 760	4 760	4 760	4 760	4 760	4 760	4 760
less Cash farm costs	17 520	15 330	15 900	14 639	16 981	17 571	19 655	21 382	22 951	24 881
plus Off farm income	6 000[a)]	6 000	6 000	6 000	6 000	2 964				
plus Gross farm revenue	12 028	14 604	16 317	18 753	21 087	29 212	33 855	35 471	37 807	36 367
less Loans 1 and 2 repaid + interest	19 743	26 789	32 233	41 379	44 690	46 470	46 470	46 470	46 470	46 470
less Tax paid					66	1 290	1 243	1 290	1 697	598
equals Cumulative cash balance	-1 715	-6 185	-9 915	-16 625	-17 668	-15 584	-13 858	-12 289	-10 359	-10 701

a) The opportunity cost of the manager's labour was estimated as $7000 per annum. This figure was subsequently reduced by $1000 to take into account the additional salary which would need to be paid to employ a full time manager if the owner worked off the farm for an entire year.

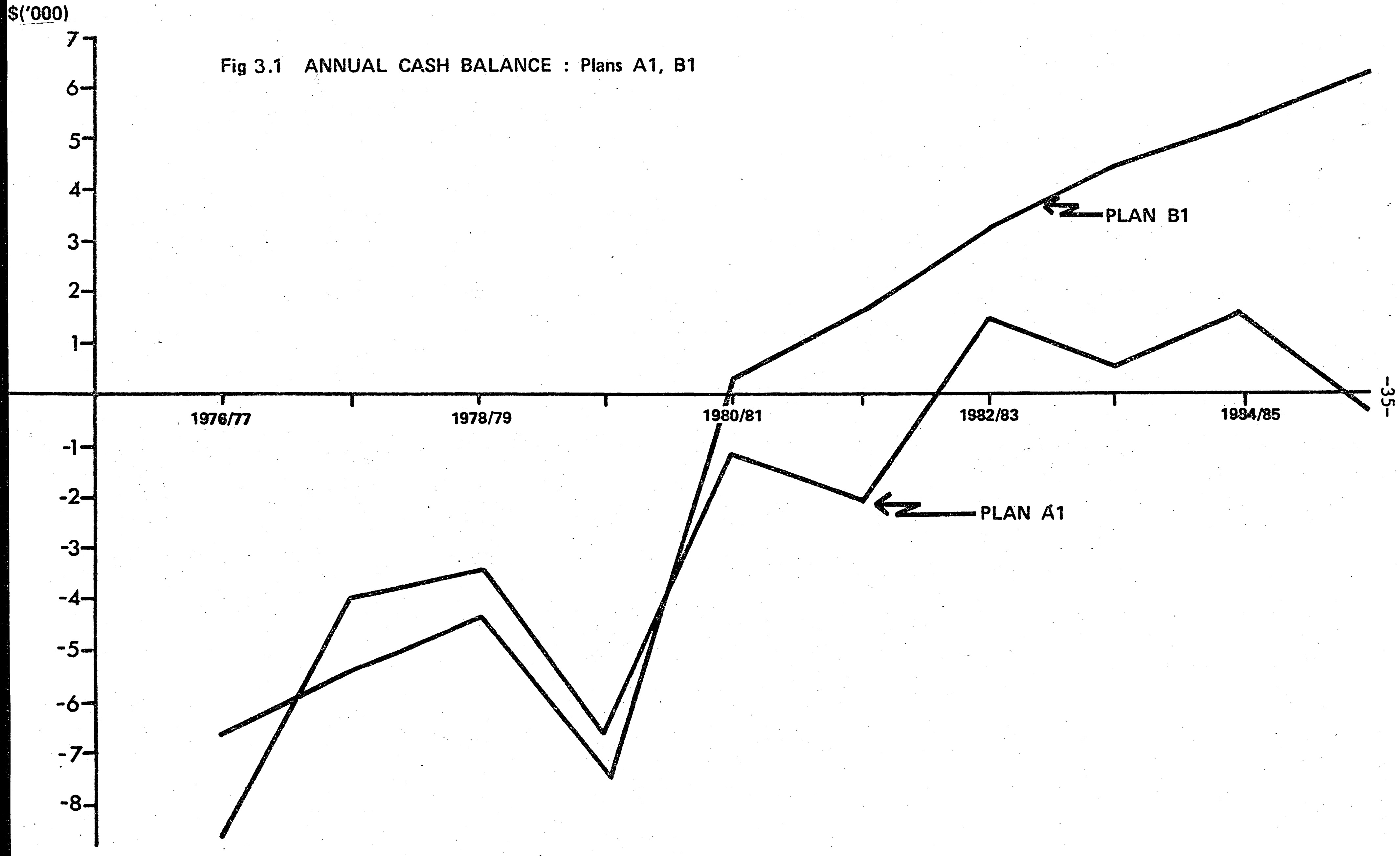
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Fig 3.1 ANNUAL CASH BALANCE : Plans A1, B1
PLAN B1
PLAN A1
1976/77
1978/79
1980/81
1982/83
1984/85

between 1980/81 and 1985/86 is due to the planting programme undertaken during these years.

3.2.4 Labour requirements

In addition to cash, labour acts as another limiting resource in orchard production. Table 3.7 lists the extra labour requirements for plans A1 and B1, which is needed to supplement the manager's contribution.

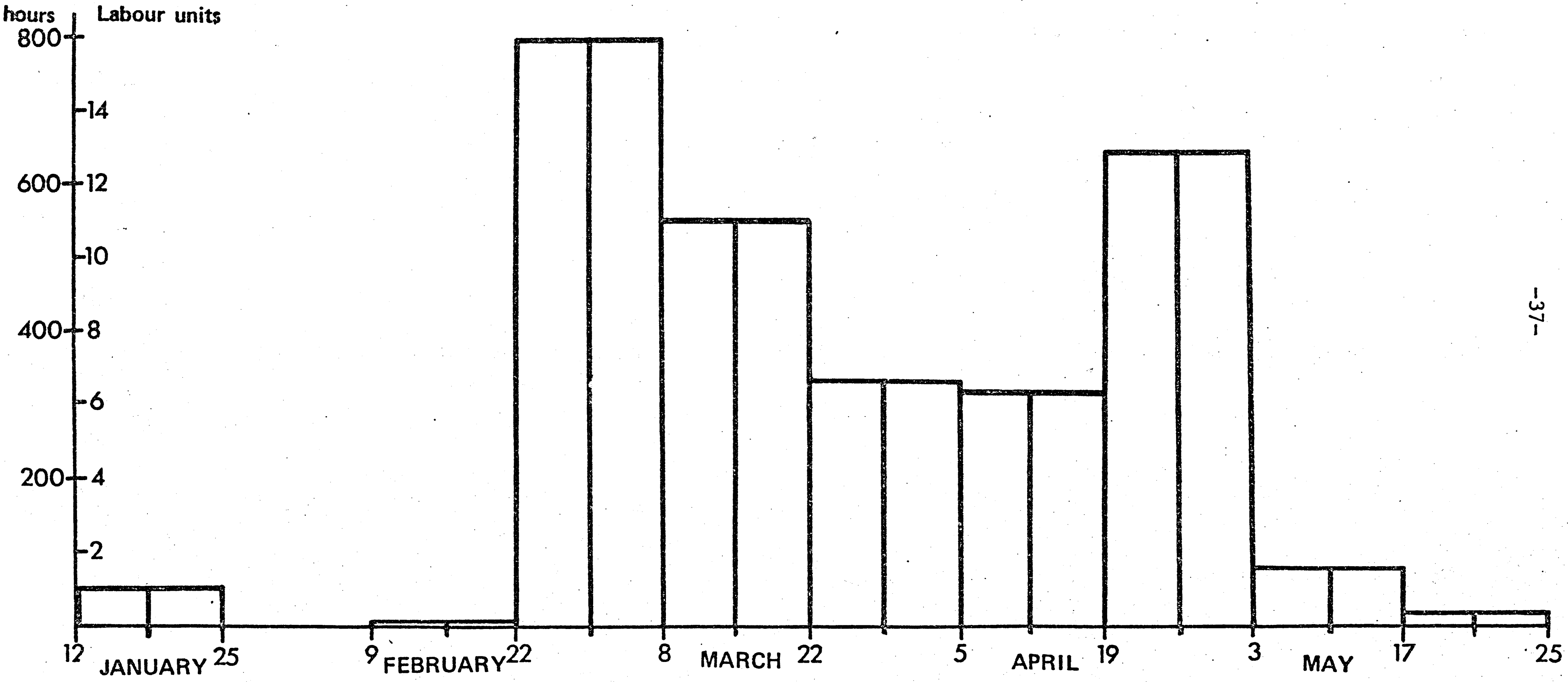
Table 3.7 Additional Labour Requirements: Plans A1, B1 (hours)

Year	Plan A1			Plan B1		
	Period I[a)]	Period II[b)]	Period III[c)]	Period I	Period II	Period III
1976/77	523	944	1462	246	56	1560
1977/78	541	716	1626	289	56	1723
1978/79	642	716	1684	297	56	1782
1979/80	608	716	1860	324	56	1937
1980/81	618	866	2039	332	56	2104
1981/82	508	647	2025	362	56	2312
1982/83	430	564	1966	386	56	2676
1983/84	925	660	1688	403	56	2742
1984/85	816	781	1657	385	56	2755
1985/86	618	1088	1442	414	56	2979

a) June - August = 14 weeks
b) September - December = 16 weeks
c) January - May = 22 weeks.

Assuming a 44 hour week, one man employed full time could work 616 hours in period 1, 704 hours in period 2 and 968 hours in period three. Accordingly, plan B1 would require either the use of contract labour or part time work of one man to assist with pruning during the winter and early spring months. The adjustment plan A1 by comparison, would demand the equivalent of an extra man to be employed throughout periods I and II. The labour provided by this additional labour unit could be supplemented from time to time by casual or contract labour. During the

Fig 3.2 HARVEST LABOUR REQUIREMENTS IN 1985/86 : PLAN B1



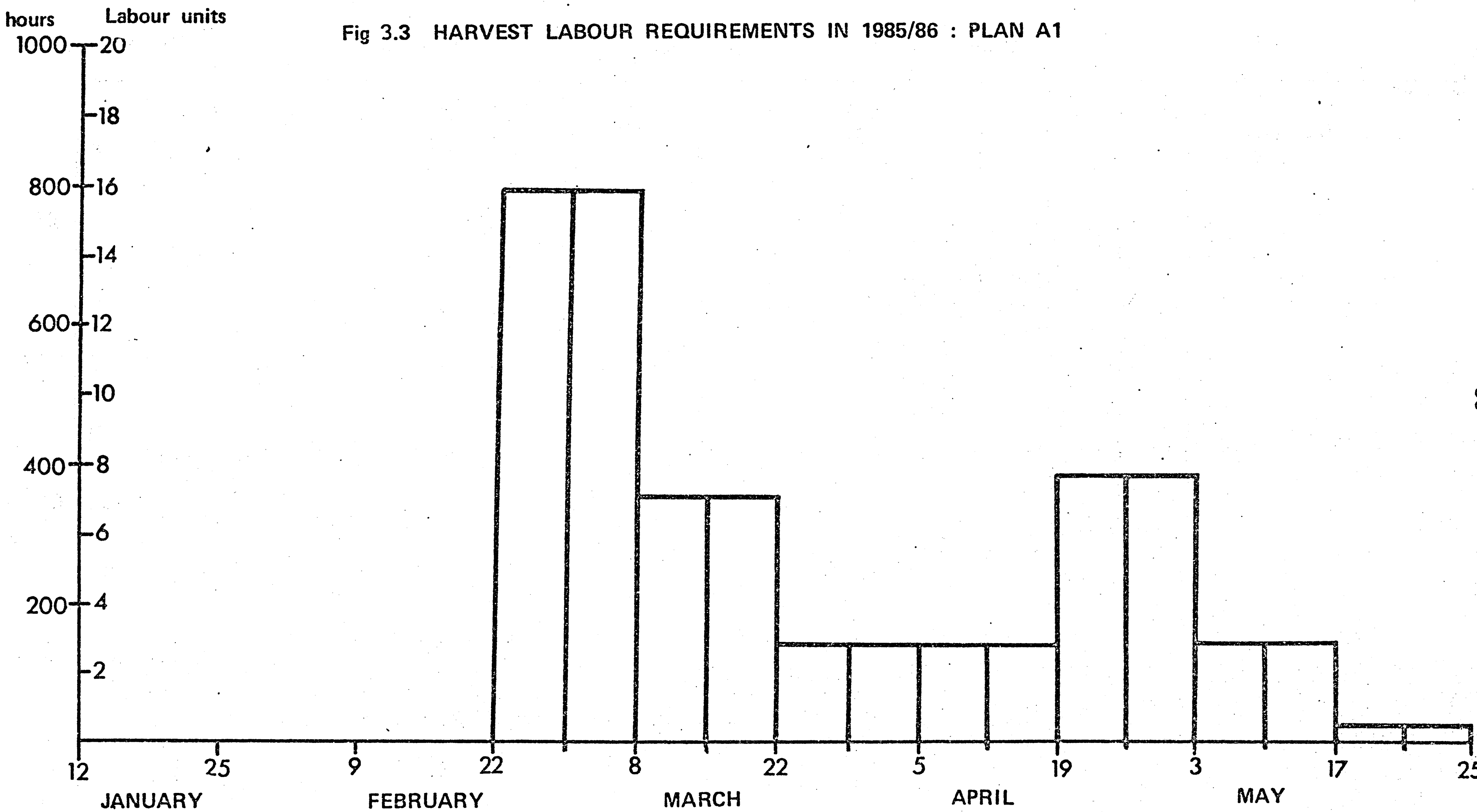


Fig 3.3 HARVEST LABOUR REQUIREMENTS IN 1985/86 : PLAN A1

harvest period, additional labour also needs to be employed to:

(a) maintain the orchard property; and

(b) harvest the fruit.

The labour requirements for the former are also indicated in table 3.7 with the equivalent of as many as three additional men being required to supplement the work of the manager for plan B1 and two men for plan A1. The lower harvest season labour requirement by the adjustment plan reflects the lower percentage of bearing trees in existence in plan A1 as a result of the tree removal and planting programme.

The labour requirement for fruit picking is shown as an additional requirement above that required for the harvest season discussed above. The weekly pattern of labour demand throughout the harvest period for the final year of the planning horizon is shown for plant A1 and B1 in figures 3.2 and 3.3 respectively. Again, the lower demand for picking labour in plan A1 in comparison with plan B1 reflects the lower yields realized in 1985/86 by the restructured orchards. It is anticipated that the weekly labour demand will even out in plan A1 as the non-bearing Red Delicious trees come into bearing.

3.3 Partial Adjustment

For a variety of reasons some growers may not be prepared to undertake an extensive programme of tree planting. In order to determine the benefit which might accrue from the removal of some existing trees without the attendant adjustment activities involving tree planting or tree replacement, the I.L.P. model was solved with "tree removal" as the sole adjustment activity. The resultant plan, plan A3 in which the value of final assets and final cash were weighted equally, will now be compared with plan B1 in order to determine the benefit that is likely to accrue from the removal of selected trees.

Table 3.8 Orchard Adjustment: Plan A3

Variety	Initial tree numbers	Tree removals		Final tree numbers Plan A 3
		1976/77	1983/84	
Granny Smith	734			734
Cox	724			724
Red Delicious	436			436
Richared	82			82
Gala	159			159
Golden Delicious	332	51		281
Delicious	280			280
Sturmer	558		317	241
Red Dougherty	152			152
Gravenstein	229	229		
Jonathan	263	263		
Rome Beauty	49	49		
Splendour.	118			
Packhams	163			163
Winter Cole	52			52
TOTAL TREE NOS.	4331	873	317	3422

The orchard adjustment strategy shown in table 3.8 indicates that it would be profitable for the manager to immediately remove all Gravenstein, Jonathan, Rome Beauty and Golden Delicious trees greater than 50 years of age. The overall reduction in tree numbers proposed by plan A3 is 1190 or 27 percent of the initial tree numbers. The effect of this reduction in tree numbers is reflected by a reduce yield of fruit over the ten year planning horizon. The magnitude of the yield reduction is shown in table 3.9.

The financial implications of this tree removal programme is shown in table 3.10 which presents a summary of the expected cash flow from plan A3 together with the cumulative cash balance of plan B1 which has been included for comparative purposes. By comparing the cash flow derived from plan B1 in table 3.5 with the cash flow from plan A3 it can be seen that the removal of unprofitable trees has the effect of immediately reducing the total variable costs. This reduction in total variable costs

Table 3.9 Pip Fruit Production: Plans B1, A3

Year	Plan B1	Plan A3
1976/77	17 473	13 985
1977/78	19 126	15 696
1978/79	19 722	16 351
1979/80	21 301	18 010
1980/81	22 997	19 785
1981/82	25 112	21 981
1982/83	27 252	24 245
1983/84	27 927	23 497
1984/85	28 062	23 830
1985/86	29 394	25 348

leads to a corresponding reduction in the need for loan finance. Accordingly, the debt structure for plan A3 is less onerous than that outlined for plan B1. In plan A3 a peak debt of $28,211 occurs in 1978/79 and the average indebtedness over the planning horizon is $19,938. Plan B1 by comparison, reaches a peak debt of $39,212 in 1981/82 with an average indebtedness of $30,936.

The tree removal programme also has the effect of reducing gross farm revenue in comparison with the benchmark situation. For example in 1976/77 the gross farm revenue is reduced from $15,300 to $13,855, a fall of 10 percent. However, as the change in revenue is less than the change in costs the net effect of tree removal is to increase annual net income. This increase in annual income is reflected in the increased level of taxation in plan A3 and the increased level of after tax cash at the end of the planning horizon.

The overall effects of an adjustment programme which consists of tree removal alone is summarised in table 3.11. In this table the present value of the objective function for plan A3 is compared with the presented value of the objective function of the benchmark plan. Both components of the objective function show an increase in plan A3 when compared with plan B1. The increase in the present value of final cash has already been discussed.

Table 3.10 Cash Flow Summary: Plan A3

Cash flow items	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Opening cash balance	7 000	1 797	-1 738	-4 222	-9 633	-7 763	-4 293	414	5 832	12 314
plus Loan 1 received	11 165	16 893	20 963	28 211	28 130	26 964	24 664	19 645	14 577	8 176
less Personal drawings	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000
less Cash fixed costs	4 760	4 760	4 760	10 760	4 760	4 760	4 760	4 760	4 760	4 760
less Cash farm costs	10 405	10 930	11 466	10 229	10 738	10 441	12 612	12 299	12 660	12 731
plus Gross farm revenue	13 855	16 507	18 419	20 835	23 630	27 181	30 809	31 759	34 026	36 484
less Loan 1 repaid + interest	12 058	18 245	22 641	30 468	30 381	29 121	26 637	21 216	15 743	8 830
less Tax paid					1 012	2 352	3 757	4 699	5 967	7 522
equals Cumulative cash balance	1 797	-1 738	-4 222	-9 633	-7 763	-4 293	414	5 942	12 314	20 132
Plan B1 Cumulative cash balance	131	-5 429	-9 939	-17 456	-17 240	-15 158	-11 800	-7 595	-2 306	3 949

Table 3.11 Present Value of the Objective Function: Plant B1, A1, A3 ($)

Objective function component	Plan B1	Plan A1	Plan A3
Present value of final cash	2 007	-5 439	10 234
Present value of final assets	170 309	468 223	17 144
Present value of objective function	172 316	462 784	181 682

The increase in the present value of final assets has resulted from the removal of those varieties which possessed negative final asset values.

3.4 Alternative objectives

Although the maximization of final assets and final cash may act as a suitable objective for some growers, an equal weighting of these goals need not necessarily be the most appropriate weight to assign such goals. For example, growers approaching retirement and without heirs to transfer their orchard to might well wish to maximize final cash. An objective function which assigned a zero value to the final assets activity would therefore be appropriate in this case.

In order to examine the sensitivity of the solution of the adjustment model to the objective function, parametric programming techniques were employed to vary the weight of the final assets activity in the objective function. This in effect permits an analysis of alternative adjustment strategies under various rates of time preference. Five plans, A1, A5, A6, A7, A8 and A9 corresponding to final asset values of 1.0, 0.8, 0.6, 0.4, 0.2 and 0.0 respectively were selected to illustrate the way in which the solution changed as the weight given to the final assets activity was reduced and the importance on cash received during the planning period increased.

The present value of the objective function for each of these selected plans is given below in table 3.12.

Table 3.12 Value of the Objective Function: Plans A1, A5 - A9

Plan	Weight of final assets	Present value of final cash	Present value of final assets	Weighted present value of final assets	Present value of objective function
A1	1	-5 439	468 223	468 223	462 784
A5	0.8	-5 173	467 900	374 320	369 147
A6	0.6	-4 548	466 956	280 174	275 625
A7	0.4	-2 589	462 827	185 131	182 541
A8	0.2	4 055	437 288	87 457	91 513
A9	0	19 029	351 344	-	19 029

The present value of the objective function is derived by combining the present value of final cash with the present value of final assets, multiplied by the appropriate weight. As the weight given to the coefficient of the final assets activity is decreased the importance of final cash is increased proportionately until in plan A9 the objective function maximizes the value of final cash alone. The results of the plans given in table 3.12 suggest that relatively minor changes occur for values of the final assets activity between 1.0 and 0.2. The plan which maximizes the value of final cash however, appears to have changed considerably from plan A1.

The tree reconciliation statement shown in table 3.13 summarizes the structural adjustment specified by the various plans. In general terms there is a gradation in tree numbers between plan A1 and plan A9, with the rate of planting decreasing as the weight given to the value of the final assets decreases. Relatively minor changes occur between plans A1 to A8 with respect to the number of trees planted and the years in which these plantings occur. Perhaps the most significant feature of these plans relates to the absence of reworking as an adjustment strategy in plans A1 to A7. Reworking Golden Delicious to Gala does, however, enter the optimal solution in plans A8 and A9 but at a minor level with only 142 and 162 trees being reworked in each plan. The level of tree removals fluctuates between 1800 and 2600 trees and fails to show any significant trend between the various plans. Interplanting like reworking tends to become a more

Table 3.13 Tree Reconciliation Statement: Plans A1, A5 - A9

	Plan A1	Plan A5	Plan A6	Plan A7	Plan A8	Plan A9
Initial tree number	4331	4331	4331	4331	4331	4331
No. of trees reworked to Gala[a)]					142	162
less removals	2060	2738	1876	2665	2509	1911
plus no. of trees interplanted						
Granny Smith	477	483	487	317	949	792
Packhams				194		
Gala				2		
plus no. of trees planted						
Granny Smith	201	26				
Cox	1246	1234	1225	1191	391	
Red Delicious	1662	1645	734	1588	1509	
Gala	831	823	817	792	608	
Packhams	1661	1646	1634	1393	1509	
Winter Cole	831	822	816	794	754	
equals final tree number	9180	8227	8168	7937	7542	3212
TOTAL NEW PLANTINGS	6909	6634	5713	6271	5720	792

a) As reworked trees do not involve a change in tree numbers they are not included in the actual tree reconciliation.

favoured option as more importance is placed on final cash as opposed to final assets. The reason being due to the earlier cash returns which may be expected from these strategies as opposed to the delayed pattern of returns to be expected from planting a new orchard block. This fact is supported in plan A9 where new plantings are completely omitted and the adjustment strategy revolves about the removal of the less profitable varieties, interplanting and reworking some existing trees.

The loan requirements for the various plans are shown in table 3.14. The loan requirements vary corresponding to the structural adjustments which were described above. Plans A5 through A8 show a similar demand for loan finance as that outlined for plan A1. However in plan A9 the requirement for borrowed funds is reduced because of the lower level of tree planting and the greater level of income earned off the farm.

Table 3.14 Loan Requirements: Plans A1, A5-A9 ($)

Year	Plan A1	Plan A5	Plan A6	Plan A7	Plan A8	Plan A9
1976/77	18 280	18 052	18 190	18 946	20 268	15 769
1977/78	24 805	24 584	24 735	25 851	26 857	19 472
1978/79	29 845	29 626	29 791	31 309	32 308	21 672
1979/80	38 314	38 109	38 280	40 110	41 041	27 397
1980/81	41 367	41 727	41 589	42 021	43 000	24 893
1981/82	43 000	43 000	43 000	43 000	43 000	21 991
1982/83	43 000	43 000	43 000	43 000	43 000	17 816
1983/84	43 000	43 000	43 000	43 000	43 000	12 037
1984/85	43 000	43 000	43 000	43 000	35 260	4 508
1985/86	43 000	43 000	43 000	43 000	35 260	

The percentage of time that the manager is required to work off the farm is set out in table 3.15. Again, the requirement is seen to be quite similar for plans with final assets weights ranging between 1 and 0.4. However, plans A8 and A9 which place greater emphasis on the value of final cash demands that the manager supplement farm income by working off the farm for all or most of the planning horizon.

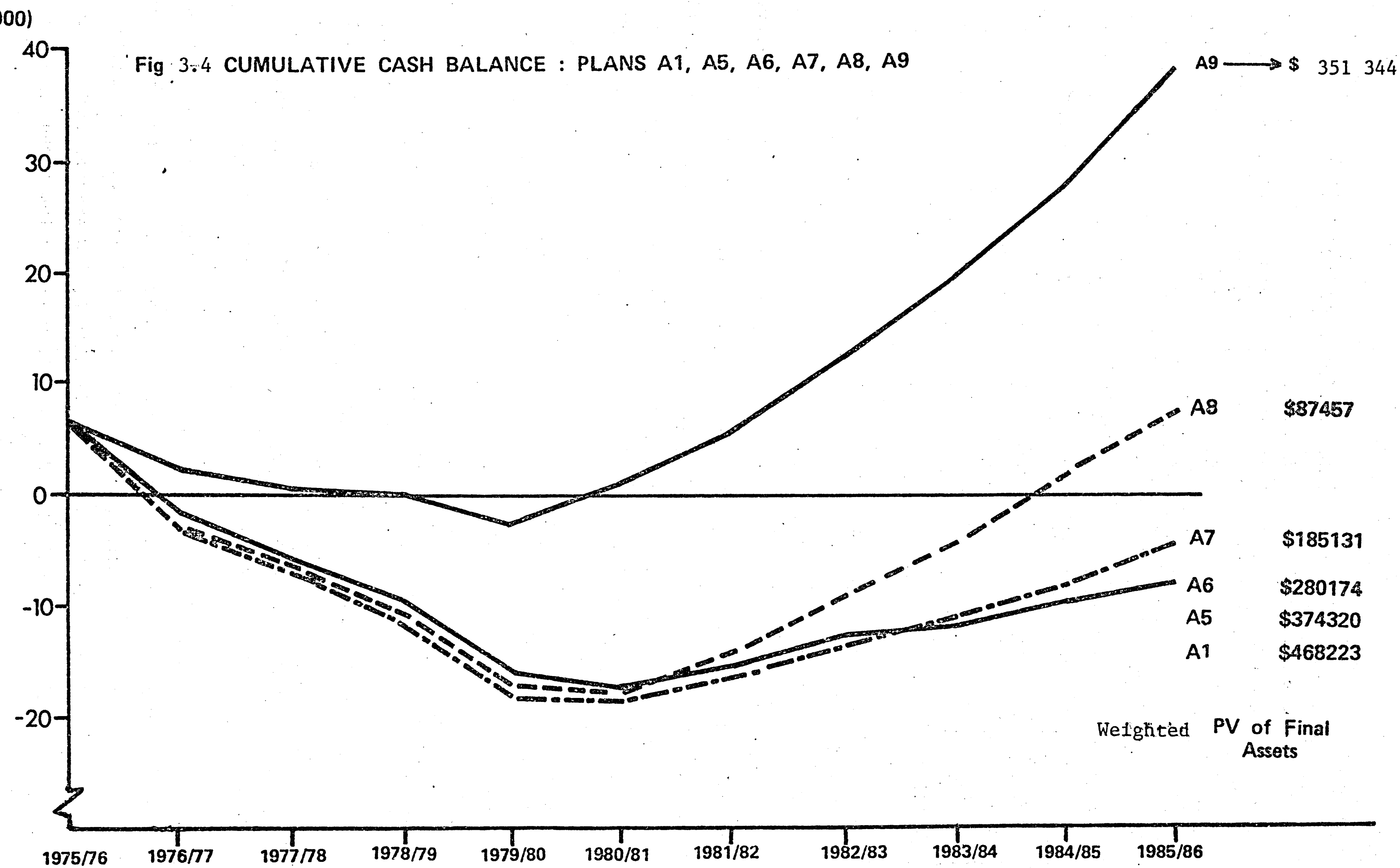
Table 3.15 Percentage of Year Worked off the Orchard (%)

Year	Plan A1	Plan A5	Plan A6	Plan A7	Plan A8	Plan A9
1976/77	100	100	100	100	100	100
1977/78	100	100	100	100	100	100
1978/79	100	100	100	100	100	100
1979/80	100	100	100	100	100	100
1980/81	100	100	100	100	92	100
1981/82	49	50	49	17	31	100
1982/83					47	100
1983/84					100	100
1984/85					100	100
1985/86					100	100

The financial results of the various plans are summarised in figure 3.4 which plots the cumulative cash flow for each of the plans under discussion. The similarity of plans A5, A6 and A7 with plan A1 is again obvious. As the weight given to the final assets activity is decreased further, as in plans A8 and finally in plan A9, the period of indebtedness is decreased.

Because of the different pattern of adjustment specified by plan A9 a summary of the cash flow for this plan is shown in table 3.16. In addition to the reduced demand for loan finance and the greater need for work off the farm this plan shows a reduction of on farm cash costs in comparison with plan A1 as shown in table 3.6. This reduction in cash costs, especially in the latter years of the plan is a result of the lower level of tree planting in plan A9. As a result of the lower costs in plan A9, surplus cash is generated by 1985/86 with the result that $3738 is made available for investment off the farm in that year.

In this section it has been shown that the adjustment plan outlined previously(plan A1) is somewhat insensitive for values of the final assets coefficient in the objective function between 1.0 and 0.4. As the value of this coefficient falls to 0.2 and finally to 0.0 greater emphasis is placed on adjustments which produce a return within the planning horizon.



$('000)
40
30
20
10
0
-10
-20
Fig 3.4 CUMULATIVE CASH BALANCE : PLANS A1, A5, A6, A7, A8, A9
A9 → $ 351 344
A8 $87457
A7 $185131
A6 $280174
A5 $374320
A1 $468223
Weighted PV of Final Assets
1975/76
1976/77
1977/78
1978/79
1979/80
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86

Table 3.16 Cash Flow Summary: Plan A9

Cash flow items	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Opening cash balance	7 000	2 171	596	104	-2 870	788	5 886	12 200	18 770	27 181
plus Loan 1 received	15 769	19 472	21 672	27 397	24 893	21 991	17 816	12 037	4 508	
less Personal drawings	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000	3 000
less Cash fixed costs	4 760	4 760	4 760	10 760	4 760	4 760	4 760	4 760	4 760	4 760
less Cash farm costs	15 009	13 883	14 509	13 741	14 263	15 019	15 942	16 476	15 518	15 682
less Off farm investment										3 738
plus Off farm income	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
plus Gross farm revenue	13 202	15 692	17 867	21 006	23 929	27 507	30 783	31 611	33 955	37 394
plus Investment repaid + interest										4 000
less Loan 1 repaid + interest	17 031	21 030	23 406	29 588	26 884	23 750	19 242	13 000	4 869	
less Tax paid		65	357	288	2 257	3 872	5 341	5 841	7 906	9 959
equals Cumulative cash balance	2 171	597	104	-2 870	788	5 886	12 200	18 770	27 181	37 435

For example, orchard restructuring consisted of reworking and interplanting. In addition, the level of off farm work increased in order to supplement income in the short run. This shift in adjustment strategies is also reflected in the rate of return which was computed from the shadow price of initial cash. The step function plotted in figure 3.5 shows how the rate of return decreases as the objective function gives greater weight to the value of cash at the end of the planning horizon. This decrease in the rate of return is caused by the corresponding decrease in the "value" of the investment in perennial crops which consequently effects the value of the objective function. (See table 3.12)

3.5 Capital restrictions

The final set of plans to be considered are based on the model with a final assets weight of 0.2 (plan A8). In this analysis the effect of capital restrictions was examined by varying the level of initial cash between -$8000 and $22,000. The value of the objective function for a number of selected plans within this range is shown in table 3.17.

Table 3.17 Value of the Objective Function: Plans A10,...,A15

Plan number	Initial cash ($)	P.V. of final cash ($)	P.V. of final assets ($)	P.V. of objective function ($)	Percentage change Base = Plan A8 (%)
A10	-8 000	-4 815	77 446	72 629	-21
A11	-3 000	-1 540	81 156	79 616	-13
A12	2 000	1 044	84 602	85 646	-7
A8	7 000	4 055	87 457	91 513	0
A13	12 000	6 835	90 471	97 360	+6
A14	17 000	10 863	92 009	102 872	+12
A15	22 000	14 179	94 084	108 265	+18

The orchard restructuring programmes corresponding to these plans is shown in the tree reconciliation statement in table 3.18. Changing the initial owned cash has little effect on the various adjustment strategies. The main contributor to the difference between the value of the objective

Fig 3.5 RATE OF RETURN FOR PLANS A1, A5 - A9

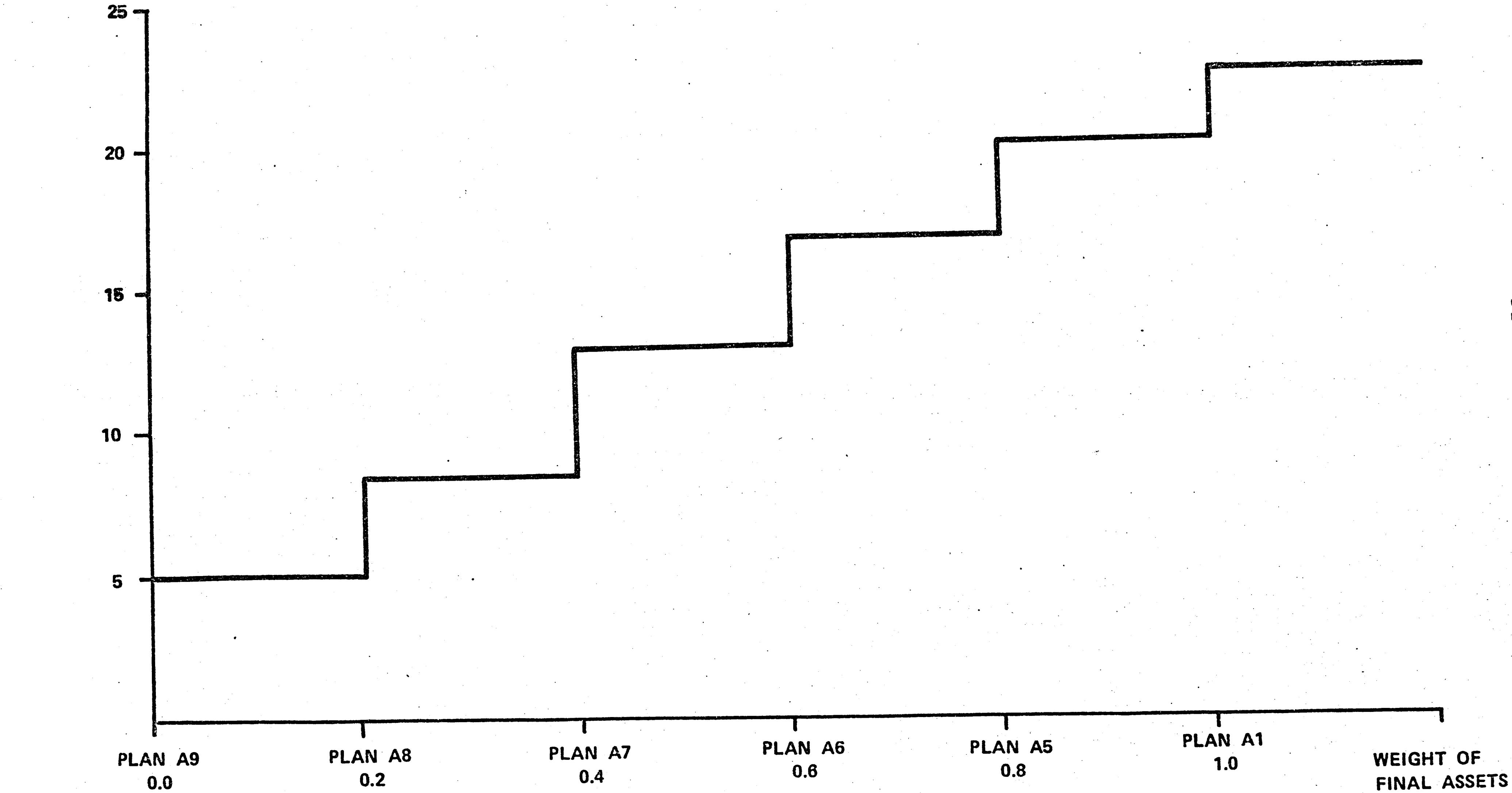


Table 3.18 Tree Reconciliation Statement: Plans A10, ..., A15

	Plan A10	Plan A11	Plan A12	Plan A8	Plan A13	Plan A14	Plan A15
Initial tree number	4 331	4 331	4 331	4 331	4 331	4 331	4 331
No. of trees reworked to							
Gala	162	162	162	142	162	162	162
Less removals	2 541	2 353	1 691	2 509	2 601	2 463	1 899
Plus no. of trees interplanted							
Granny Smith	949	949	949	949	949	949	949
Plus no. of trees planted							
Gala	580	573	584	608	712	591	591
Cox	400	181	305	391	422	386	386
Red Delicious	1 486	1 470	1 492	1 509	1 522	1 477	1 504
Packhams	1 484	1 470	1 491	1 509	1 523	1 506	1 506
Winter Cole	743	735		754	761	753	753
Equals Final tree number	7 432	7 356	7 461	7 542	7 619	7 530	7 530
TOTAL NEW PLANTINGS	5 642	5 378	4 821	5 720	5 889	5 662	5 098

function of plan A8 and the other plans shown in table 3.18 being in the rate at which old trees were removed. The level of off farm work also remained reasonably constant through these plans.

4.0 Summary and Conclusions

The linear programming results in this paper suggest that a further decline in the welfare of Moutere Hill pip fruit producers will occur within the next decade.

Regardless of whether or not growers decide to undertake a development programme aimed at restructuring their orchards, it is likely that considerable loan finance will be required. The amount of finance needed increasing in proportion to the amount of development undertaken.

Although the financial prospects for the short and medium term indicated a period of severe financial difficulty, the prospects for the long term appear quite favourable. The results have shown that considerable financial gains can be expected after 1990 when perennial crops enter full bearing.

In order to evaluate the various plans that were discussed, a number of criteria were used. These criteria included the pattern of indebtedness, the present value of expected income, etc. If producers were operating in an environment of certainty the task of drawing conclusions from the results of the L.P. analysis would be relatively simple. The potential increase in income noted in the adjustment model over that indicated by the benchmark model would suggest that considerable potential exists for increasing income and that if possible growers should be encouraged to maintain and develop their properties.

However, fruit growers do not operate in an environment of complete certainty so the fact that expected benefits do not begin to accrue until the late 1980's, about 14 years after the commencement of the planning horizon, leaves an extensive period of time during which the factors responsible for uncertainty could affect the original assumptions upon which the I.L.P. models were based. In addition, the added indebtedness demanded by persevering with fruit growing on the Moutere Hills is likely to be unacceptable to a number of growers regardless of the potential return from borrowing.

It should be noted that some adjustment has already occurred in the benchmark situation. It is largely as a result of this adjustment which occurred shortly before the start of the planning horizon that the financial results from this plan become more favourable towards the end of the planning horizon. This fact highlights the major problem of Moutere Hill pip fruit growers, i.e., adjustment has been delayed for too long. As this study has shown that potential for increased incomes does exist the question that needs to be answered addresses itself to whether or not it is too late to rectify the errors of judgement that have been made in the past. In some cases it will be obvious that no alternative exists and growers will be forced to withdraw from the industry. In other cases where growers are able, and willing, to borrow amounts as indicated in the previous section, orchard restructuring could still occur.

At this stage we could do well to head the advice of William Shakespeare who, when contemplating change, suggests:

> "If it were done when 'tis done, then 't were well
> It were done quickly".
>
> Shakespeare, Macbeth, (I, vii).

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APPENDIX A

In this appendix a simplified representation of the year 10 submatrix is presented. Activities have been numbered as -

(K)P(N)

and restraints as (K)R(S) for K = 1, ..., 10 years of the planning horizon
N = 1, ..., 120 activities per year.
S = 1, ..., 60 restraints per year.

Activities 9P001-10P 087 may be interpreted as follows.

Existing tree activities are transferred from year nine to year ten via activities 9P001, ..., 9P030. In year 10 these trees may be retained (10P001, ..., 10P030), removed (10P031, ..., 10P060), interplanted (10P074, ..., 10P082) or reworked (10P083, ..., 10P087). In addition, new trees may be planted (10P074, ..., 10P073). The requirements for trees which have been interplanted, reworked or planted in previous years are represented by activities (K)P061, ..., (K)P087, where K is the year in which the activity was initiated.

The following legend should assist in the interpretation of the input output coefficients.

A = number of hectares/100 trees
B = resource supply
D = (1 - marginal tax rate)
F = final asset value/100 trees
H = harvest labour requirement/100 trees
L = seasonal labour requirement/100 trees
P = proportion of variety j
R = total revenue/100 trees
T = trees of variety j (T=1)
V = variable cost/100 trees
X = number of existing trees required/100 interplanted trees
Y = yield of pip fruit (bushels)/100 trees.

The revised simplex algorithm incorporated in the Burroughs TEMPO mathematical programming system was used to obtain optimal feasible solutions to the I.L.P. model. However, because of the size of the L.P. matrix and the consequent problem of handling the large quantity of data, the GAMMA matrix generator and report writer were used to specify the data, the structure of the model and the form of the solution reports.

Simplified Submatrix - Year 10

RESTRAINT	R.H.S.	Existing orchard trees year 9	Plant new trees years 1,...,9	Interplant old trees years 1,...,9	Graft old trees in year 10	Hire labour	Variety proportion	Loan 1	Loan 2	Off farm work	Off farm investment	Graft old trees years 1,...,9	Existing orchard trees year 10	Remove old trees	Plant trees in year 10	Interplant old trees in year 10	Tax deduction transfer	Taxation activities	Final cash surplus	Final cash deficit	Final assets
		9P001...9P030	KP061...KP073	KP074...KP082	10P083...10P087	10P088...10P099	10P100	10P101	10P102	10P103	10P104	KP083...KP087	10P001...10P030	10P031...10P060	10P061...10P073	10P074...10P082	10P105	10P106...10P117	10P118	10P119	10P120
OBJECTIVE FUNCTION																			1	-1	1
10R001 Existing	0 =	-1			1								1	1		X					
⋮ Orchard	0 =	-1			1								1	1		X					
10R030 Trees	0 =	-1			1								1	1		X					
10R031 Land	13 ≥		A A A	A A A	A A A							A A A	A A A	-A -A -A	A A A	A A A					
10R032 Yield			Y Y Y	Y Y Y	Y Y Y							Y Y Y	Y Y Y		Y Y Y	Y Y Y					
10R033 Labour Period A	520 ≥		L L L	L L L	L L L	-1				520		L L L	L L L	L L L	L L L	L L L					
10R034 Labour Period B	720 ≥		L L L	L L L	L L L	-1				720		L L L	L L L		L L L	L L L					
10R035 Labour Period C	680 ≥		L L L	L L L	L L L	-1				680		L L L	L L L		L L L	L L L					
10R036 Harvest	0 ≥		H H H	H H H	H H H	-1						H H H	H H H		H H H	H H H					
⋮ Labour	0 ≥		H H H	H H H	H H H	-1						H H H	H H H		H H H	H H H					
10R044 Periods 1-9	0 ≥		H H H	H H H	H H H	-1						H H H	H H H		H H H	H H H					
10R045 Cash Requirement	-B ≥		V V V	V V V	V V V	V V V V V V		-1	-1		1	V V V	V V V	V V V	V V V	V V V					
10R046 Tax Deductions	B ≥		-V -V -V	-V -V -V	-V -V -V	-V-V-V-V-V-V		-.08	-.10			-V -V -V	-V -V -V	-V -V -V	-V -V -V	-V -V -V	1				
10R047 Before Tax Cash	0 ≥		-R -R -R	-R -R -R	-R -R -R	-R-R-R-R-R-R				-6000	-0.07	-R -R -R	-R -R -R		-R -R -R	-R -R -R	1	1 1 1			
10R048 Variety	0 ≥		T T T	T T T	T T T		.P					T T T	T T T		T T T	T T T					
⋮ Proportions	0 ≥		T T T	T T T	T T T		.P					T T T	T T T		T T T	T T T					
10R058 Constraints	0 =		1 1 1	1 1 1	1 1 1		-1					1 1 1	1 1 1		1 1 1	1 1 1					
10R059 Final Cash	-B ≥							1.08	1.10		-1						-1	-D -D -D	1	-1	
10R060 Final Assets	0 ≥		-F -F -F	-F -F -F	-F -F -F							-F -F -F	-F -F -F		-F -F -F	-F -F -F					1

APPENDIX B

Table B1 Distribution of Some Characteristics Used in the Determination of the Moutere Hills Representative Orchard (percentage of farms)

Area of pipfruit (ha)	(%)	Total area (ha)	(%)	Percentage development (%)	(%)	Off-farm income ($)	(%)
4.0 - 8.0	16.6	4.0-12.0	22.4	20- 40	5.5	0	6
8.1 - 12.0	61.4*	12.1-20.0	33.3*	41- 60	33.5	1- 500	11
12.1 - 16.0	5.5	21.0-28.0	16.6	61- 80	44.4*	501-1000	22
16.1 - 20.0	5.5	More than 28.1	27.7	81-100	16.6	1001-1500	28*
21.1 - 24.0	5.5					1501-2000	17
More than 24.1	5.5					More than 2001	16

Percentage of high valued varieties (%)	(%)	Net farm income ($)'000	(%)	Percentage equity (%)	(%)
10 - 20	5.5	Less than 0	44.4*	20- 40	11.7
21 - 30	38.8*	0 - 2	11.2	41- 60	17.6
31 - 40	22.2	2.1- 4	11.2	61- 80	35.2
41 - 50	11.4	4.1- 6	16.6	81-100	35.5*
51 - 60	16.6	6.1- 8	-		
61 - 70	5.5	More than 8	16.6		

* = modal value.

Table B2 Comparison of the Representative Orchard With the Sub-sample Mean and Modal Group Values

Characteristics	Mapua sub-sample			Selected representative farm
	Mean	Median	Modal group	
Percentage development (%)	63	63	61-80	61
Percentage high values varieties (%)	36	33	21-30	30
Net farm income 1974/75 ($)	1145	1681	Lt. 0	-2394
Apple production (bush bearing ha)	1737	1684	1720-2470	1503
Area in pip fruit (ha)	12.14	10.92	8.09-12.04	8.65
Total area of holding (ha)	24.68	15.78	12.14-20.03	15.78
Percent supplied to A.P.B. (%)	97	99	90-100	99
Off farm income ($)	2773	587	1001-1500	53
Percentage equity (%)	73	71	81-100	51
Total density of pip fruit plantings (trees/ha)	417	408	Gt.420	408

Table B3 Variety Composition of the Representative Orchard

Variety	Representative Orchard (tree numbers)				Mapua %
	Non-bearing	Bearing	Total	%	
Granny Smith	492	242	734	18	19
Cox	376	348	724	17	14
Red Delicious	342	176	518	12	14
Gala	159		159	4	3
Golden Delicious	71	261	332	8	9
Sturmer	42	516	558	14	14
Red Dougherty		152	152	4	6
Gravenstein		229	229	5	3
Jonathan		263	236	6	7
Others	118	49	167	4	5